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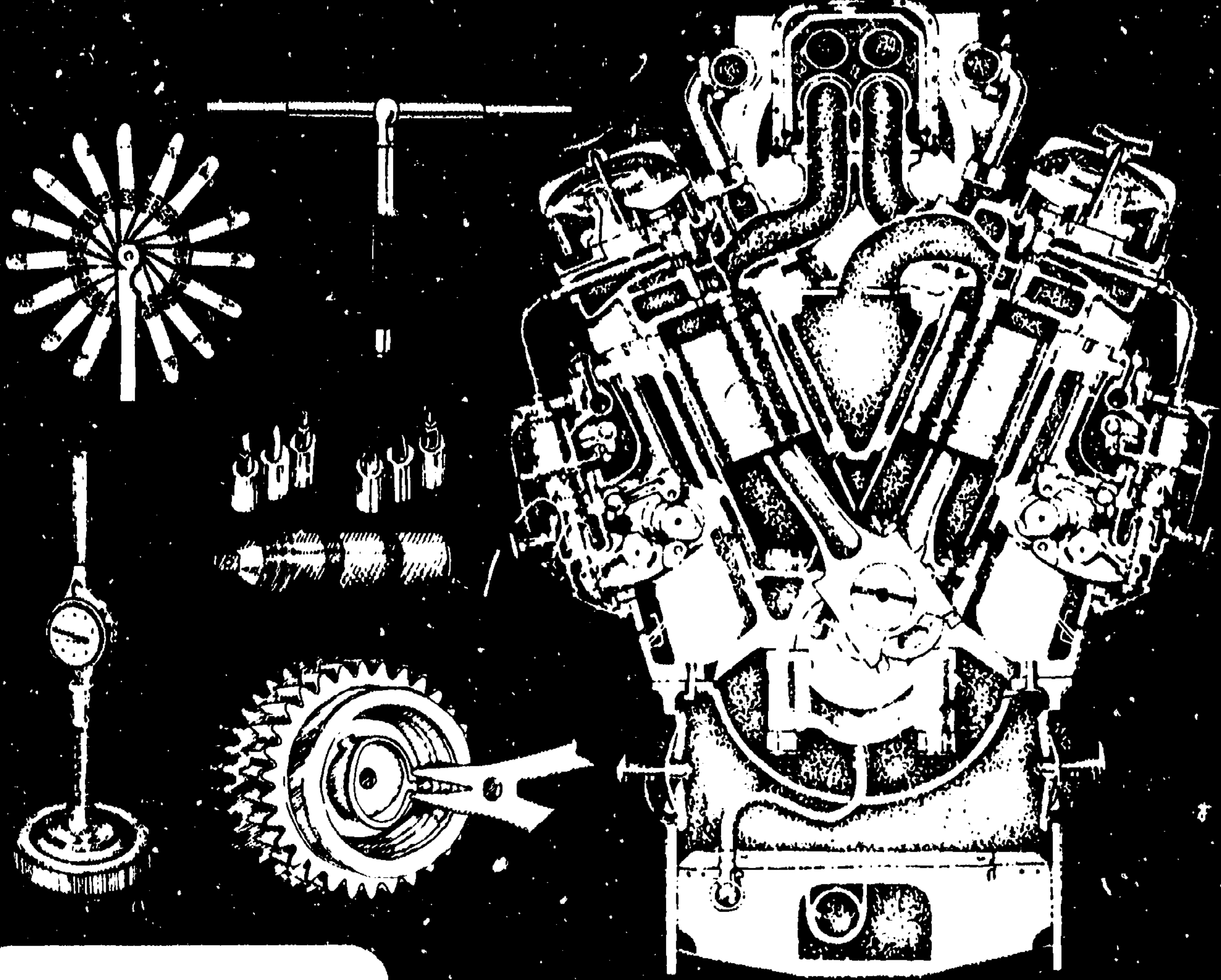
ABSTRACT

This module is one of a series of teaching guides that cover diesel mechanics. The module contains eight instructional units that cover the following topics: (1) introduction to electrical systems; (2) electrical circuits; (3) electrical indicator circuits; (4) storage batteries; (5) starting systems and circuits; (6) ignition circuits; (7) alternator charging circuits; and (8) emergency shut-down circuits. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use for more than one lesson or class period. Instructional task analyses; a list of tools, equipment, and materials; and 14 references are also included. (KC)

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DIESEL ELECTRICAL SYSTEMS

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Developed by

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DIESEL ELECTRICAL SYSTEMS

TABLE OF CONTENTS

FOREWORD

Both the development and revision of instructional materials in diesel mechanics have been rewarding efforts because of the talented people who planned and wrote the materials. From the team of teachers and industry representatives has come a series of texts which should offer diesel mechanics students an excellent opportunity for learning required skills.

This publication, *Diesel Electrical Systems*, is designed to be used with the other MAVCC books related to diesel. These include: *Diesel Fundamentals, Diesel Fuel Systems, Power Trains*, and *Hydraulics*.

As complex as some mechanical activities are, the MAVCC format presents the procedures in logically ordered objectives that facilitate a comfortable learning rate. The format also frees the instructor to concentrate on reinforcing classroom instruction with films, supplemental resources, and other teaching activities that serve to maintain student interest at a high level and to motivate students to learn and do.

Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from these publications: motivation, personalization, and localization. Those areas are left to the individual instructors and the instructors should capitalize on them. As these publications are used, it is hoped that student's performance will improve and that students will be better able to assume a role in diesel mechanics.

Ron Mehrer, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Greg Pierce
Executive Director
Mid-America Vocational
Curriculum Consortium

ACKNOWLEDGEMENTS

Appreciation is extended to those individuals who contributed their time and talent to the development of *Diesel Electrical Systems*.

The contents of this publication were planned and reviewed by:

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Special appreciation is extended to those who served on the original advisory committee representing the many MAVCC states, and to the original author, William Foutes, and to the authors of the second edition, Bill Guynes, Marvin Kukuk, and Joe Mathis.

USE OF THIS PUBLICATION

Instructional Units

Diesel Electrical Systems contains eight units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

DIESEL ELECTRICAL SYSTEMS

INSTRUCTIONAL TASK ANALYSIS

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT I: INTRODUCTION TO ELECTRICAL SYSTEMS

1. Terms and definitions
2. Safety practices dealing with electrical systems
3. Particles in an atom
4. Electricity according to the atomic theory
5. Sources of electricity
6. Parts of a basic circuit
7. Conductors and insulators of electricity
8. Copper as a conductor
9. Circuit terms and units of measure
10. Basic electrical schematic symbols
11. Letter designations and terms
12. Ohm's Law formula in triangle expression
13. Ohm's Law in letter formula
14. Types of electrical circuits
15. Factors affecting resistance in a conductor
16. Characteristics of magnetism

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
17. Relationship between electricity and magnetism	
18. Electromagnetic induction	
19. Ways to induce voltage by electromagnetic induction	
20. Factors that determine the magnitude of induced voltage	
21. Types of electric current	
22. Direct and alternating current	
23. Instruments used in checking electrical circuits	
	24. Solve problems using Ohm's Law

UNIT II: ELECTRICAL CIRCUITS

1. Terms and definitions
2. Rules for series circuits
3. Rules for parallel circuits
4. Rules for series-parallel circuits
5. Basic electrical circuit failures
6. Voltage drop
7. Types of circuit protection
8. Selection of cable for various rewiring needs
9. Characteristics of a wiring diagram
10. Parts of a typical circuit identification code

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
11. Types of connectors	
12. Steps in troubleshooting electrical systems	
	13. Read a wiring diagram
	14. Check voltage
	15. Check a circuit for an open
	16. Install a soldered terminal
	17. Install a solderless terminal
	18. Splice a wire (solder method)

UNIT III: ELECTRICAL INDICATOR CIRCUITS

1. Terms and definitions	
2. Electrical indicator circuits	
3. Electric gauge operation design	
4. Operation of the fuel, temperature, and oil pressure magnetic gauges	
5. Sending units	
6. Operation of the oil pressure and temperature indicator light circuits	
7. Charging indicator circuits	
	8. Test gauges and sending units (tank unit method)
	9. Test gauges and sending units (grounded wire method)
	10. Test oil pressure indicator light
	11. Test temperature indicator light

RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT IV: STORAGE BATTERIES

1. Terms and definitions
2. Functions of a battery
3. Types of batteries
4. Characteristics of batteries
5. Voltage ratings of batteries
6. Ways of rotating battery capacity
7. Rules for installing batteries
8. Installation of battery cables
9. Types of battery terminal constructions
10. Safety rules to be observed during the care and maintenance of batteries
11. Troubleshoot a battery
12. Remove, service, and replace a battery
13. Measure specific gravity of a conventional battery
14. Load test a battery
15. Charge test a battery for three minutes

UNIT V: STARTING SYSTEMS AND CIRCUITS

1. Terms and definitions
2. Types of starting systems
3. Sources of compressed air for air starting motors

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
4. Components of a gasoline starting engine	
5. Types of starting aids	
6. Purpose of an electrical starting circuit	
7. Major parts in an electrical starting circuit	
8. Function of parts of an electrical starting circuit	
9. Major parts of a starting motor	
10. Component parts and their functions	
11. Conversion of electrical energy into mechanical energy	
12. How a starting motor is kept running	
13. Current flow in an electrical starting motor circuit	
14. Types of starter field circuits	
15. Types of starter field circuits and current flow	
16. Types of starting motor switches	
17. Engaging starter drives	
18. Types of electromagnetic or lever shift drives	
19. Operation of a series-parallel switch	
20. Operation of a transformer-rectifier unit	

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
	21. Remove and replace a starter
	22. Disassemble, test, and reassemble a starter
	23. Test a starter motor (no-load)
	24. Rebuild and test a starter solenoid
	25. Check voltage drop in a starter circuit

UNIT VI: IGNITION CIRCUITS

1. Terms and definitions
2. Purpose of an ignition circuit
3. Components of an ignition circuit
4. Functions of an ignition circuit
5. Ignition circuit components
6. Components of a distributor
7. Operation of an ignition circuit
8. Components of a distributor with a built in governor
9. Operation of a governed distributor
10. Transistorized and capacitive discharge ignition systems
11. Major components of an electronic ignition system and their functions
12. General safety precautions for electronic ignition systems

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
	13. Remove and install a distributor
	14. Remove and replace contact points and condenser
	15. Adjust dwell on an externally adjustable distributor
	16. Check and set ignition timing
	17. Remove, service, and replace spark plugs

UNIT VII: ALTERNATOR CHARGING CIRCUITS

1. Terms and definitions
2. Purpose of the alternator charging circuit
3. Alternator charging circuit components and functions
4. Major parts of an alternator
5. Construction of stator windings
6. Types of alternator circuits
7. Characteristics of a brushless alternator
8. Operation of a brushless alternator
9. Operation of a transistorized regulator
10. Safety rules for working with alternator charging circuits

RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

11. Test the Ford alternator charging circuit with external regulator

12. Remove and replace an alternator

13. Disassemble, test, and reassemble an alternator

14. Test a transistorized regulator

15. Test an S.I. series alternator

16. Test charging circuit resistance for a GM alternator

UNIT VIII: EMERGENCY SHUT-DOWN CIRCUITS

1. Terms and definitions

2. Characteristics of a coolant temperature switch gauge

3. Characteristics of an oil pressure switch-gauge

4. Steps in the operation of the magnetic switch

5. Shut-off solenoids

6. Characteristics of the overspeed contactor switch

7. Oil pressure contactor switch

8. Operation of an alarm system

9. Troubleshoot a shut-down and alarm circuit

DIESEL ELECTRICAL SYSTEMS

TOOLS, EQUIPMENT, AND MATERIALS LIST

Alternator
Alternator pulley removal tools
Alternator diode removal equipment
Alternator testing equipment
Ammeter
Armature growler with test light
Auxiliary starter button

Baking soda
Basic hand tool set
Battery
Battery anti-corrosion paste
Battery capacity tester
Battery charger
Battery clamp puller
Battery lift strap
Battery pliers
Battery post and cable cleaner
Bristle brush

Carbonpile resistor
Chalk
Circuit board
Circuit tester
Combination end wrench
Crimping pliers

Dial indicator
Distributor cam lubricant
Distributor wrenches
Dwell meter

Electrical tape
Electrical wire
Engine
Extensions, 3"- 6"- 10" by 3/8" drive

Feeler gauges
Fuel sending unit

Hex contact point adjusting tool
Hydrometer

Jumper wire

Ohmmeter

Point alignment tools

Ratchet
Resin core solder
Rubber apron
Rubber gloves

Safety glasses
Sandpaper, medium
Screwdriver
Service manuals
Shop towels
Soldering gun or iron
Solenoid
Spark plug starter wrench
Starter

Tachometer
Terminal
Test light
Timing light
Torque wrench

Variable resistor
V blocks
Vehicle
Voltmeter

Wire brush

DIESEL ELECTRICAL SYSTEMS

REFERENCES

A. Armstrong, Ivan J. *Auto Mechanics. Vol. II.* Stillwater, OK: State Department of Vocational and Technical Education Curriculum and Instructional Materials Center, 1978.

B. Blanchard and Ritchen. *Auto Engines and Electrical Systems*. 5th ed. New York: Motor, 1970.

C. Delco Remy Service Bulletin Nos. 1B-115, 1B-116, and 1B-188. Anderson, IN: 1976, 1980, 1983.

D. *Electronic Engine Controls Manual.* Radnor, PA: Chilton Book Co., 1985.

E. Foutes, William A. *Diesel Mechanics: Electrical Systems*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

F. *Fundamentals of Service: Electrical Systems*, 4th ed. Moline, IL: Deere and Company, 1979.

G. Graf, Rudolf F. and George V. Whalen. *Automotive Electronics*. Indianapolis, IN: Howard W. Sams and Co., 1970.

H. *Master Crawler 850 Service Manual.* Racine, WI: J. I. Case Company, 1975.

I. *Motor Heavy Truck Repair Manual.* 2nd ed. New York: Hearst Books, 1935.

J. *Operating and Maintenance Manual, Engine Models 3500 Mark II and 3700 Mark II Power Unit.* Harvey, IL: Allis-Chalmers, 1984.

K. Schulz, Erich J. *Diesel Mechanics*. 2nd ed. New York: Gregg Division, McGraw-Hill Book Company, 1983.

L. *Sun Model VAT 28 Instruction Manual.* Chicago, IL: Sun Electric Corporation.

M. *Swichgage® Diagnostic General Catalog 1987-88.* Tulsa, OK: Frank W. Murphy Manufacturer.

N. *Truck and Diesel Repair Manual.* 34th ed. New York: Motor, 1981.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify types of electrical circuits, distinguish between direct and alternating current, and solve problems using Ohm's Law. Competencies will be demonstrated by completing the assignment sheet and the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical systems with their correct definitions.
2. Select true statements concerning safety practices dealing with electrical systems.
3. Name two particles found in an atom.
4. Define electricity according to the atomic theory.
5. Identify three sources of electricity related to diesel engines.
6. Name parts of a basic circuit.
7. Distinguish between conductors and insulators of electricity.
8. Explain why copper is widely used as a conductor.
9. Match the basic circuit terms with their units of measure.
10. Match the basic electrical schematic symbols with their correct names.

OBJECTIVE SHEET

11. Match the letter designations used in Ohm's Law with their correct terms.

12. Draw Ohm's Law formula in triangle expression.

13. State Ohm's Law in letter formula.

14. Identify three types of electrical circuits.

15. Name three factors affecting resistance in a conductor.

16. Select from a list the characteristics of magnetism.

17. Select true statements concerning the relationship between electricity and magnetism.

18. Select true statements concerning electromagnetic induction.

19. List three ways to induce voltage by electromagnetic induction.

20. List three factors that determine the magnitude of induced voltage.

21. Name two types of electric current.

22. Distinguish between direct and alternating current.

23. Name three instruments used in checking electrical circuits.

24. Solve problems using Ohm's Law. (Assignment Sheet #1)

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate magnetic lines of force by using iron filings and a conductor.

2. Demonstrate how to make an electromagnet using 5′ of electrical wire, a soft iron bar, and a 1.5 volt battery.

3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Armstrong, Ivan J. *Auto Mechanics*. Vol. II. Stillwater, OK: State Department of Vocational and Technical Education Curriculum and Instructional Materials Center, 1978.

B. Foutes, William A. *Diesel Mechanics: Electrical Systems*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

C. *Fundamentals of Service: Electrical Systems*, 4th ed. Moline, IL: Deere & Company, 1979.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

1. *Diesel Mechanics,* 2nd ed.
Erich J. Schulz
Text, 1983, 496 pages (055639-3)
Workbook (055640-7)
Gregg/McGraw-Hill
P.O. Box 996
Norcross, GA 30091

2. *Fundamentals of Electricity and Magnetism, Training Chart Manual*
Technical Literature Department
Delco-Remy Division
General Motors Corporation
Anderson, IN 46018

B. **Filmstrips**

1. *Basic Automotive Electricity* — #A5037

(NOTE: To obtain material and correct prices, contact your nearest Mack Branch or distributor.)

2. *Electron Theory,* MSV-AT-M-2A
1 cassette, 1 filmstrip (29 frames), 1 worksheet

Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92628-0798

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Alternator (alternating current generator) — Voltage and current produced by a rotating magnetic field cutting across stationary conductors

B. Atom — Smallest unit of all matter

C. Conductor — Any material that permits passage of electric current

D. Counter emf — Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

(NOTE: This is a generator action developed in every motor.)

E. Current — Flow of electrons through a conductor, measured in amperes

F. Electrochemical — Stored chemical energy which can be converted to electrical current

G. Electrons — Particles with a negative charge in orbit around a core of protons

H. Electromagnet — A wire carrying electric current wound into a coil around an iron core creating a magnetic field

I. Electromagnetic induction — Inducing voltage in a conductor that moves across a magnetic field

J. Emf — Electromotive force or voltage

K. Insulator — Material with an extremely high resistance to current flow

L. Mutual induction — Occurs when changing current in one coil induces voltage in a second coil

M. Parallel circuit — Current has more than one path to take

N. Protons — Particles with a positive charge that make up the nucleus of the atom

O. Resistance — Opposition to current flow in a conductor

P. Self induction — Voltage which occurs in a coil when there is a change of current

Q. Semiconductor — An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator

INFORMATION SHEET

R. Series circuit — Current has only one path it can take

S. Series-parallel circuit — A circuit consisting of both series and parallel components

T. Thermocouple — Thermoelectric device used to measure temperature accurately

U. Thermoelectric — Electricity generated by heat

V. Voltage — Potential difference that causes flow of current

W. Voltage drop — Voltage loss due to resistance

X. Watt — Electrical measurement of rate of doing work

(NOTE: 746 watts = 1 horsepower.)

II. **Safety practices dealing with electrical systems**

A. When working on electrical system that is connected to the battery, remove all jewelry.

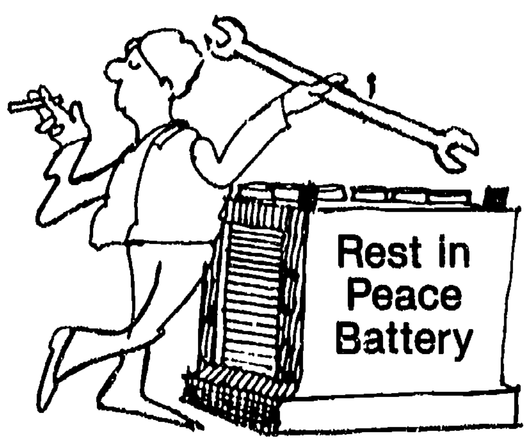
B. When disconnecting battery cables, remove the ground cable first.

C. If you are using an ohmmeter, disconnect the battery.

D. Never leave the ignition switch on when installing a distributor.

E. Never ground the output terminal of the alternator.

F. Never lay any conductor across the battery terminals.



INFORMATION SHEET

G. When replacing an electrical component, always disconnect the battery first.

H. Never apply full battery voltage to the fuel tank sending unit.

I. When using jumper cables, always connect ground to the frame or engine.

J. When using a battery charger, make your connections before plugging the charger in.

K. When adding accessories, make sure they match the vehicle's ground.

L. When replacing a conductor, always use the same size (gauge) conductor.

M. When adding accessories, be sure not to exceed the charging system output.

(NOTE: The charging system should have an output of 10% above total current draw.)

III. **Particles in an atom** (Transparency 1)

A. Electron

B. Proton

(NOTE: These are the particles involved in the electron theory.)

IV. **Electricity** — The flow of electrons from atom to atom in a conductor. (Transparency 2)

V. **Sources of electricity related to diesel engines** (Transparency 3)

A. Thermoelectric

B. Electrochemical

C. Electromagnetic

INFORMATION SHEET

VI. **Parts of a basic circuit**

A. Voltage

Example: Battery

B. Resistor

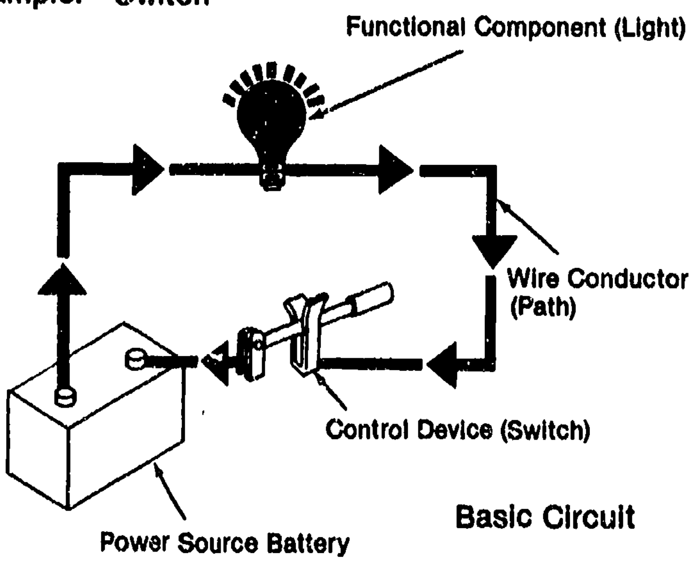
Example: Light bulb

C. Conductor

Example: Copper wire

D. Control device

Example: Switch



Basic Circuit

VII. **Conductors and insulators of electricity**

A. Conductors

1. Silver

(NOTE: Silver has the least resistance to current flow.)

2. Copper
3. Gold
4. Aluminum

INFORMATION SHEET

5. Tungsten
6. Zinc
7. Brass
8. Platinum
9. Iron
10. Nickel
11. Tin
12. Steel
13. Lead
14. Mercury
15. Nichrome

    (NOTE: Nichrome has the highest resistance to current flow.)

B. Insulators

1. Glass
2. Rubber
3. Plastic
4. Wood
5. Ceramic
6. Mica

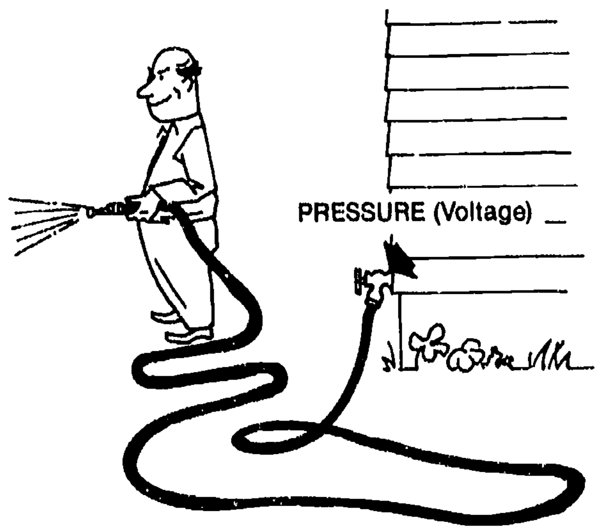
VIII. **Copper as a conductor** — Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties. (Transparency 1)

INFORMATION SHEET

IX. Circuit terms and units of measure

A. Current — Ampe·es

B. Voltage — Volts



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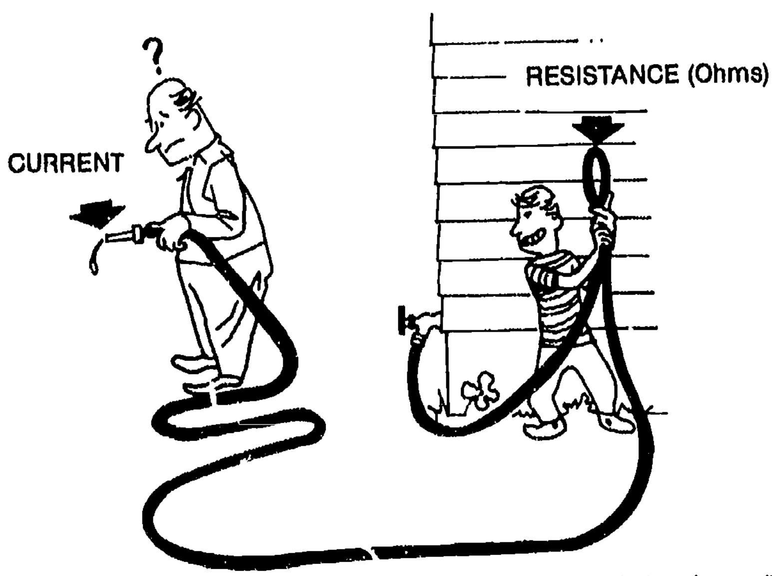
C. Resistance — Ohms



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X. Basic electrical schematic symbols

A. Resistance or load

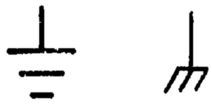
B. Ohms of resistance

C. Inductor (coil)

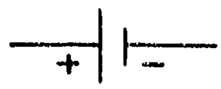
D. Inductor (solenoid)

INFORMATION SHEET

E. Ground

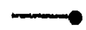


F. Battery



G. Connection

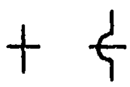
H. Termination



I. Switch — single throw

J. Switch — double throw

K. Cable — Not connected



L. Connectors — separable, engaged

M. Fuse

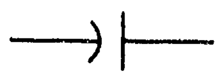
N. Circuit breaker

O. Fusible link or wire

P. Lamp

Q. Variable resistance

R. Condenser or capacitor



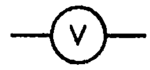
S. Direction of current

T. Diode (one-way)

INFORMATION SHEET

U. Transistor

V. Voltmeter



W. Ammeter

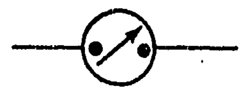
X. Positive terminal

+

Y. Negative terminal

—

Z. Gauge (temperature or fuel)



AA. Voltage limiter (for instrument panel)

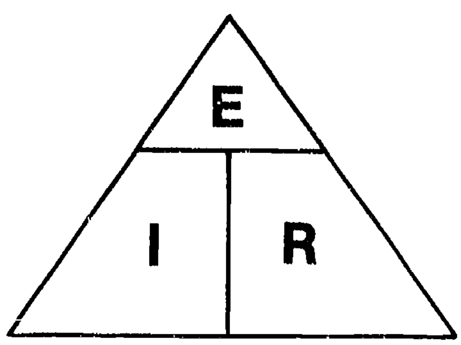
XI. **Letter designations and terms**

A. E — Electromotive force in volts

B. I — Intensity (current) in amps

C. R — Resistance in ohms

XII. **Ohm's Law formula in triangle expression** (Transparency 4)



(NOTE: E.I.R. formula reminder is the phrase "Even I Remember.")

INFORMATION SHEET

XIII. **Ohm's Law in letter formula** (Transparency 5)

A. E = I × R or Volts = Amps × Ohms

B. I = E ÷ R or Amps = Volts ÷ Ohms

C. R = E ÷ I or Ohms = Volts ÷ Amps

XIV. **Types of electrical circuits** (Transparency 6)

A. Series

(NOTE: In a series circuit the voltage will drop along the circuit. The total voltage drop in a series circuit will always be equal to the applied voltage.)

B. Parallel

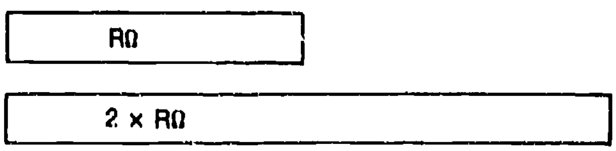
(NOTE: The voltage will be the same at all points along a parallel circuit.)

C. Series-parallel

(NOTE: The circuit is a combination of a series circuit and a parallel circuit. It has medium resistance.)

XV. **Factors affecting resistance in a conductor**

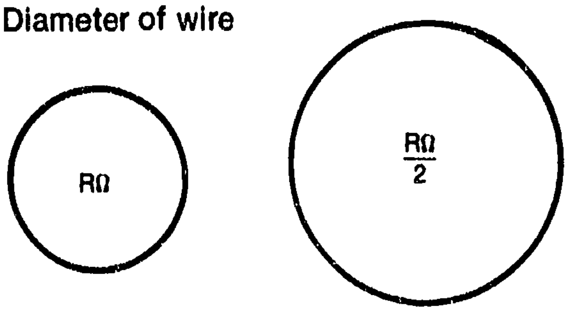
A. Length of wire



Resistance Proportional to Length

A Longer Wire Creates More Resistance

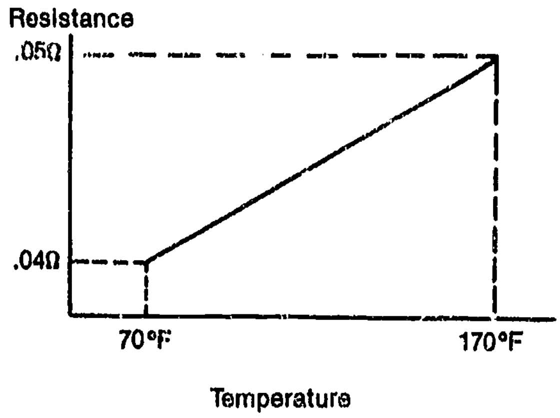
B. Diameter of wire



A Smaller Wire Creates More Resistance

INFORMATION SHEET

C. Temperature of wire



A Hotter Wire Creates More Resistance

XVI. **Characteristics of magnetism** (Transparency 7)

A. Every magnet has a north and south pole.

B. Unlike poles (charges) attract and like poles (charges) repel.

C. Every magnet has a field of force surrounding it.

D. Magnetic materials are acted upon when located in a field of force.

XVII. **Relationship between electricity and magnetism** (Transparency 8)

A. Current passed through a wire (conductor) creates a magnetic field around the wire.

B. Magnetic lines have direction and change direction when the current flow changes from one direction to another.

(NOTE: The Right Hand Rule for a straight conductor can be used to find the direction of the lines of force around the wire. To apply the rule, grasp the wire with the thumb extended in the direction of conventional current flow (positive to negative); the fingers will then point in the direction in which the lines of force surround the conductor. These lines of force are always at right angles to the conductor.)

C. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate.

(NOTE: The downward movement or rotation is caused by current flowing in the conductor. This is the principle by which a cranking motor operates.)

INFORMATION SHEET

XVIII. **Electromagnetic induction** (Transparency 9)

A. Conductor moving across a magnetic field will have a voltage (emf) induced in it.

B. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force.

(NOTE: The conductor can move or the magnetic field can move.)

XIX. **Ways to induce voltage by electromagnetic induction**

A. Generated voltage by electromagnetic induction

Examples: Generators and alternators

B. Self induction voltage created by a change of current in the conductor

Example: Primary of ignition coils

C. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil.

Example: Two windings of ignition coils

XX. **Factors that determine the magnitude of induced voltage**

A. Strength of the magnetic field

B. Speed at which lines of force are cutting across the conductor

C. Number of conductors that are cutting across the lines of force

XXI. **Types of electric current**

A. Direct

B. Alternating

INFORMATION SHEET

XXII. **Direct and alternating current**

A. Direct current

1. Supplied by

a. Generator

b. Battery

1) Dry cell

2) Wet cell

2. Flows in one direction only

3. Abbreviated as DC

B. Alternating current

1. Supplied by an alternating current generator (alternator)

2. Flows in one direction then reverses and flows in the opposite direction

3. Abbreviated as AC

XXIII. **Instruments used in checking electrical circuits** (Transparency 10)

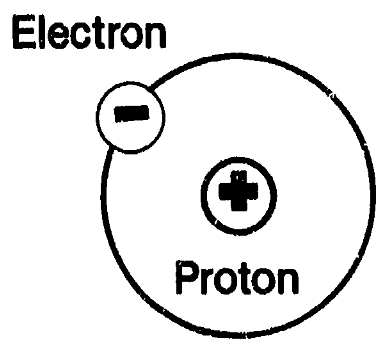
A. Ammeter

B. Voltmeter

C. Ohrnmeter

(NOTE: Modern testers often combine the voltmeter, ammeter, and ohmmeter in one test unit, such as a battery-starter tester.)

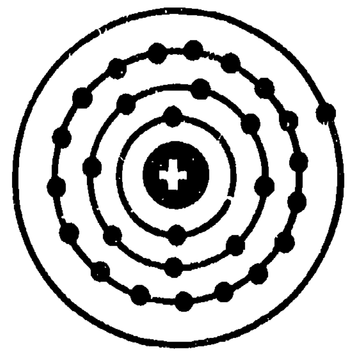
Structure of Atoms



Hydrogen Atom

1 Electron

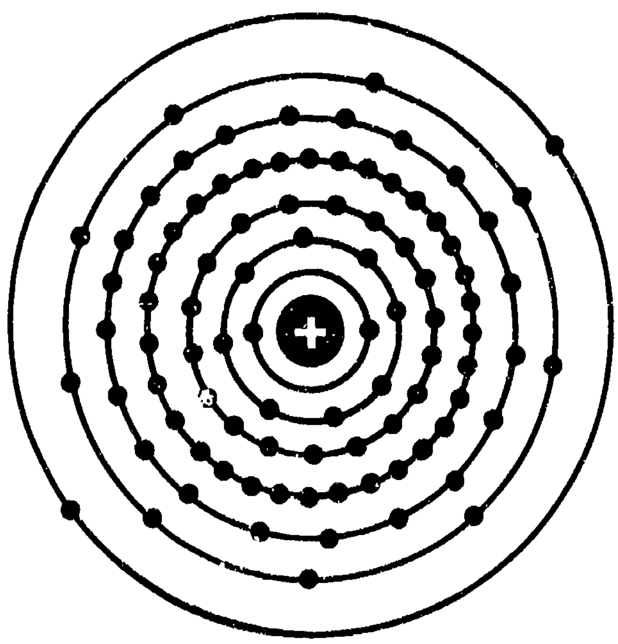
1 Proton



Copper Atom

29 Electrons

29 Protons



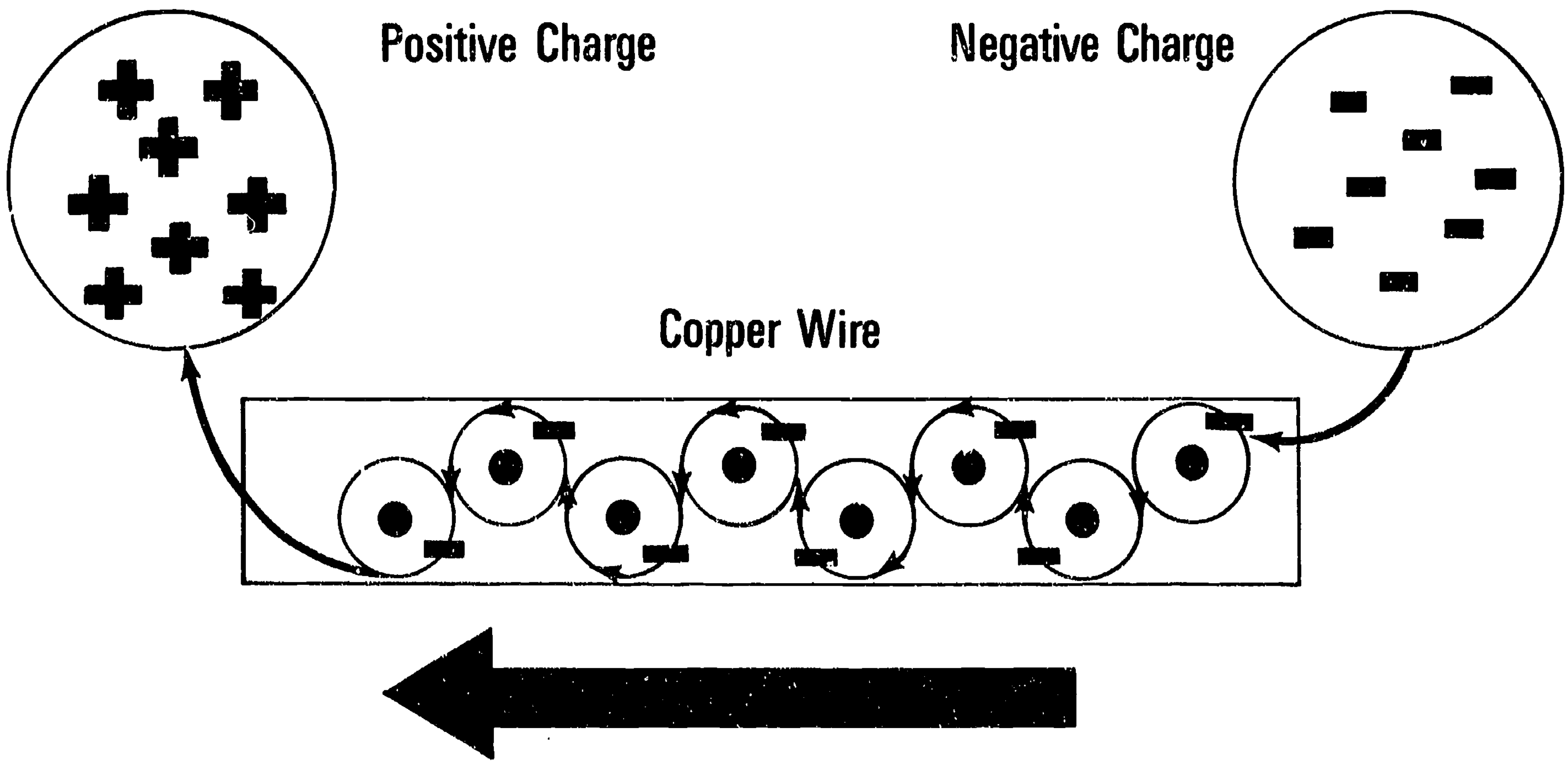
Uranium Atom

92 Electrons

92 Protons

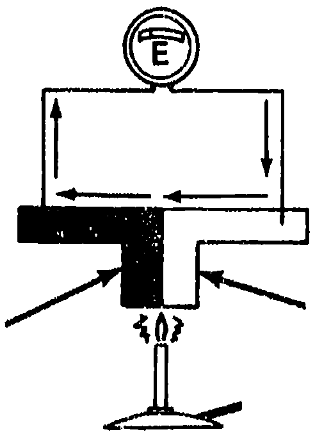
NOTE: Count the Number of Electrons in the Outer Ring of the Atom.

Electron Flow



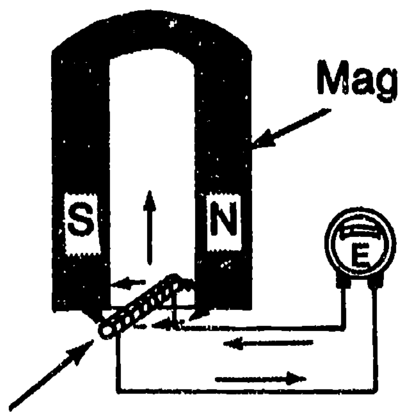
Electron Flow

Sources of Electricity



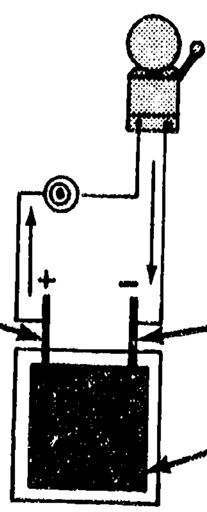
Thermocouple

Thermoelectric Source



Generator

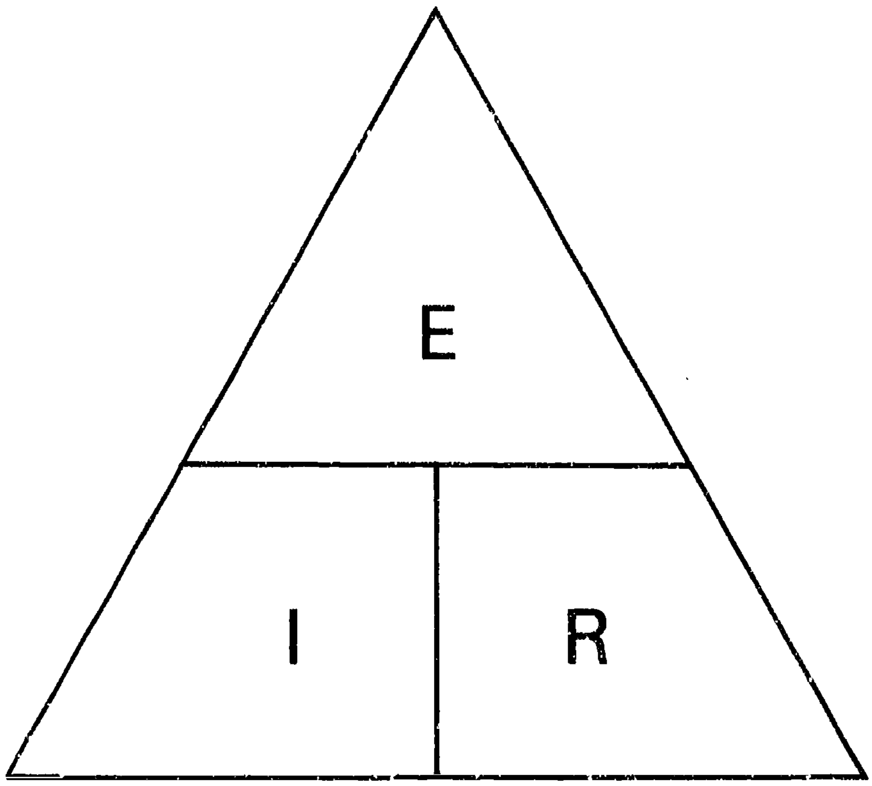
Electromagnetic Source



Battery

Electrochemical Source

Ohm's Law in Triangle Expression



E = Volts I = Amps R = Resistance

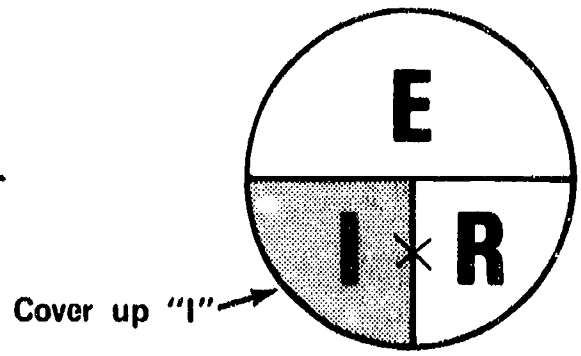
NOTE: Solve for Volts, Amps, or Resistance by Covering the Unknown

Example: Cover E, then E = I x R
Cover I, then I = E ÷ R
Cover R, then R = E ÷ I

Ohm's Law in Letter Formula

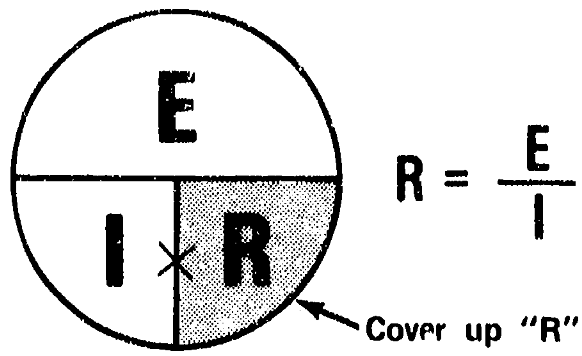
In the formula of Ohm's law,
I = amperage, E = voltage, and R = resistance in ohms.

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$



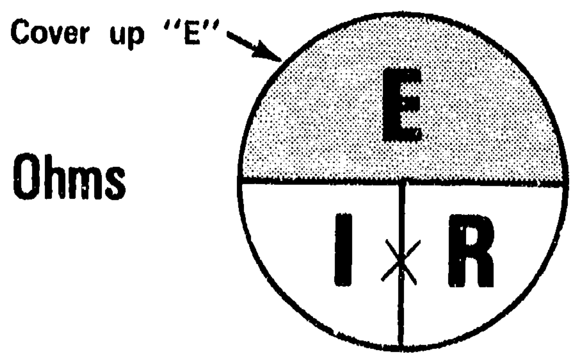
$$I = \frac{E}{R}$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$



$$R = \frac{E}{I}$$

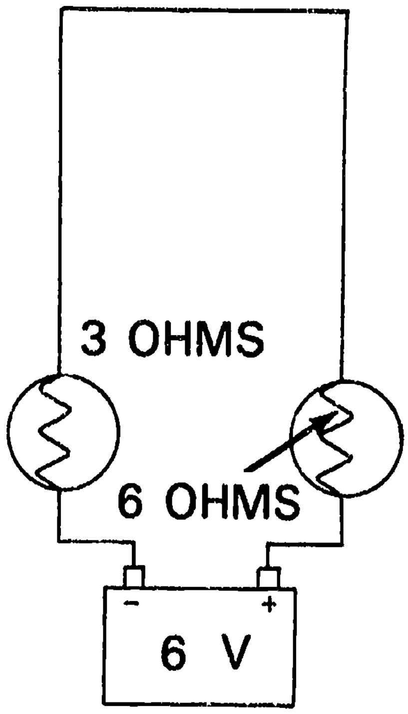
$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$



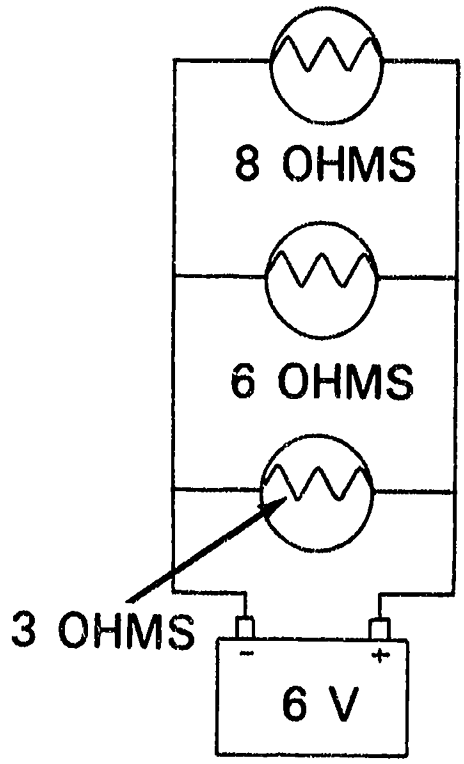
$$E = I \times R$$

(Note: If you cover the quantity you wish to calculate (voltage, current, or resistance), the remaining parts of the memory circle will show you which form of Ohm's law you must use:)

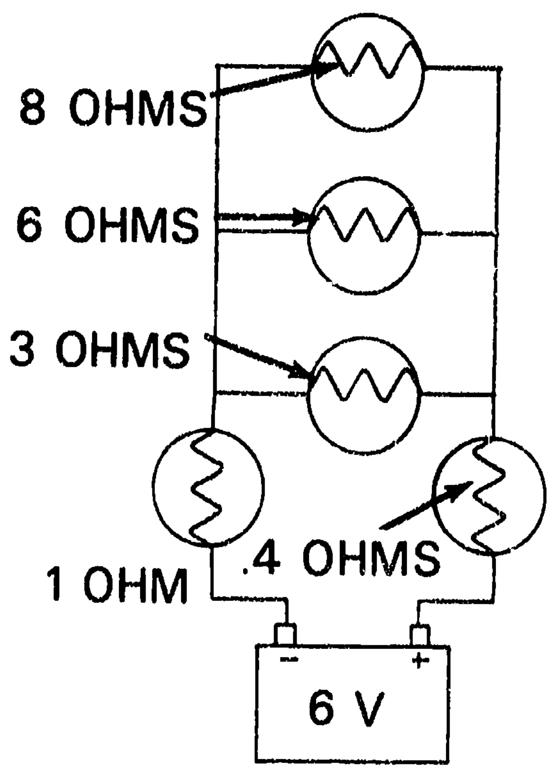
Types of Electrical Circuits



Series Circuit

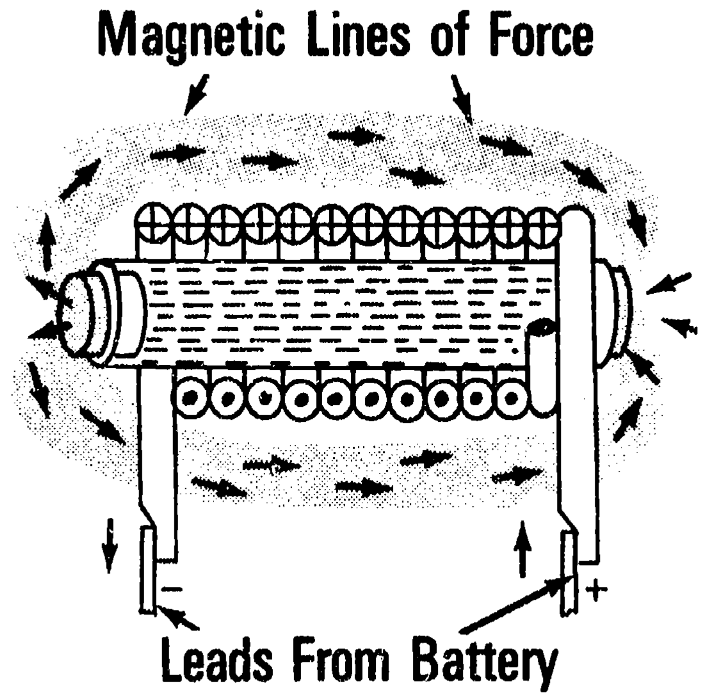


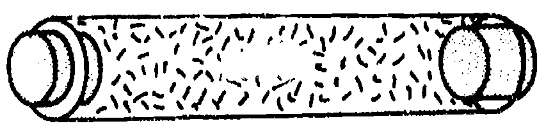
Parallel Circuit



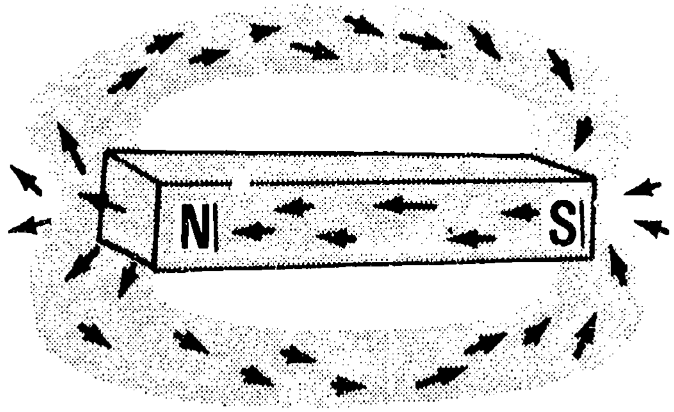
Series-Parallel Circuit

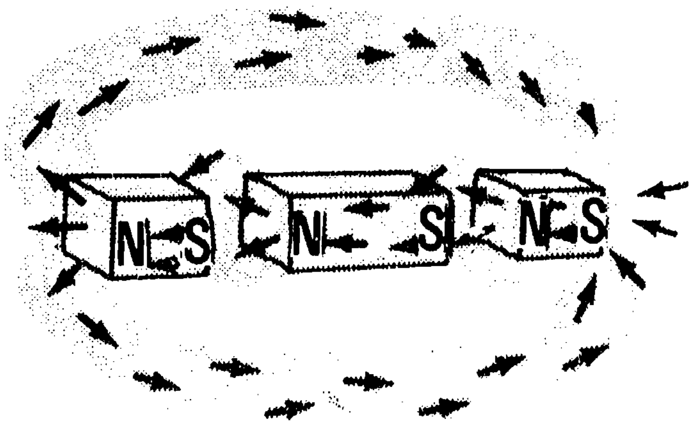
Magnetism and Field of Force



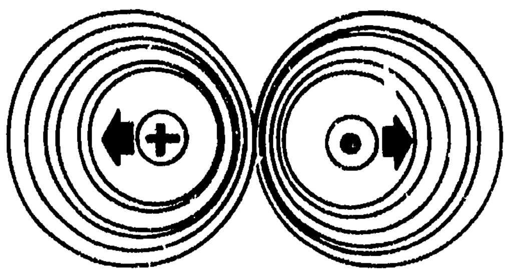


Unmagnetized Iron Filings

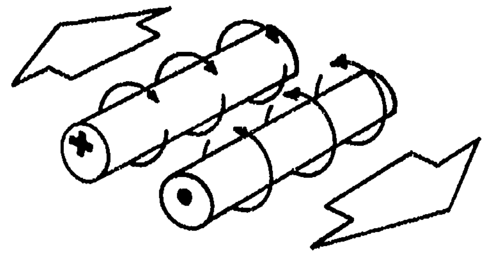




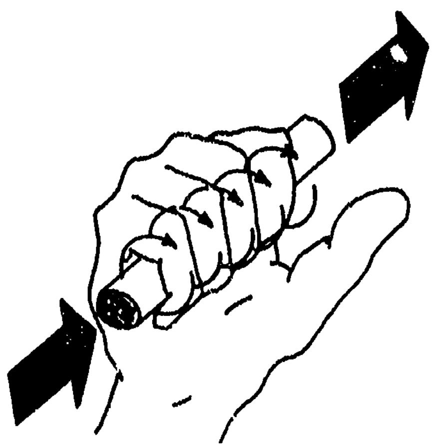
Electricity and Magnetism Relationship



Strong Field Between Conductors



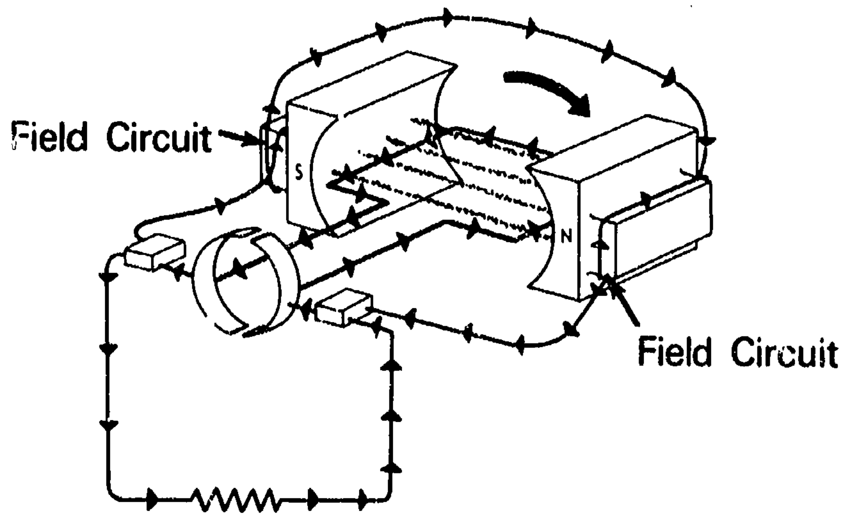
Conductors Tend To Move Apart



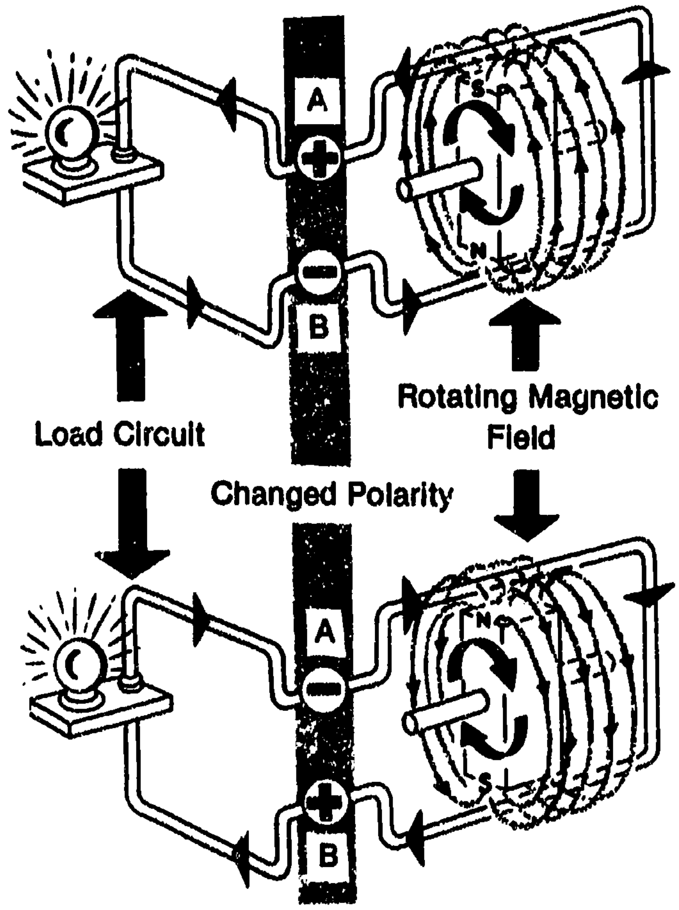
Right Hand Rule For Straight Conductor
Arrows Show Direction Of Field Of Force

Motor Principle

Electromagnetic Inductions

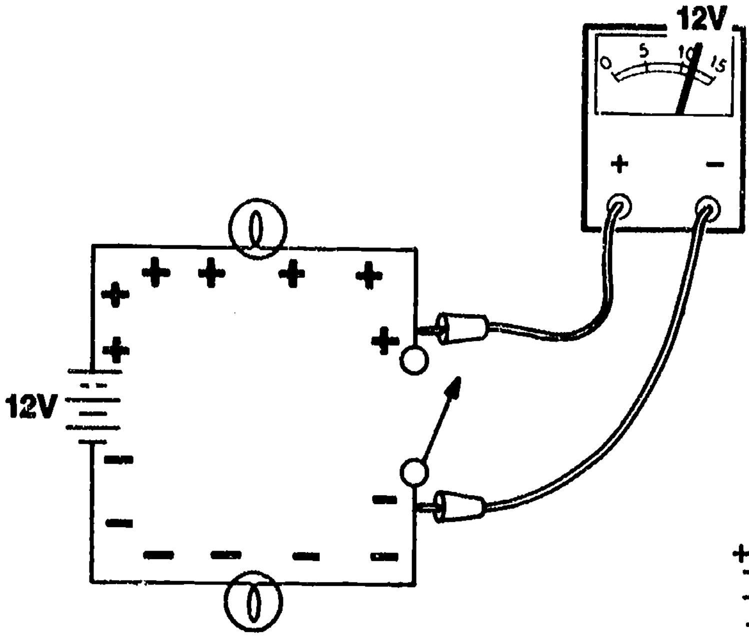


Basic Generator Operation

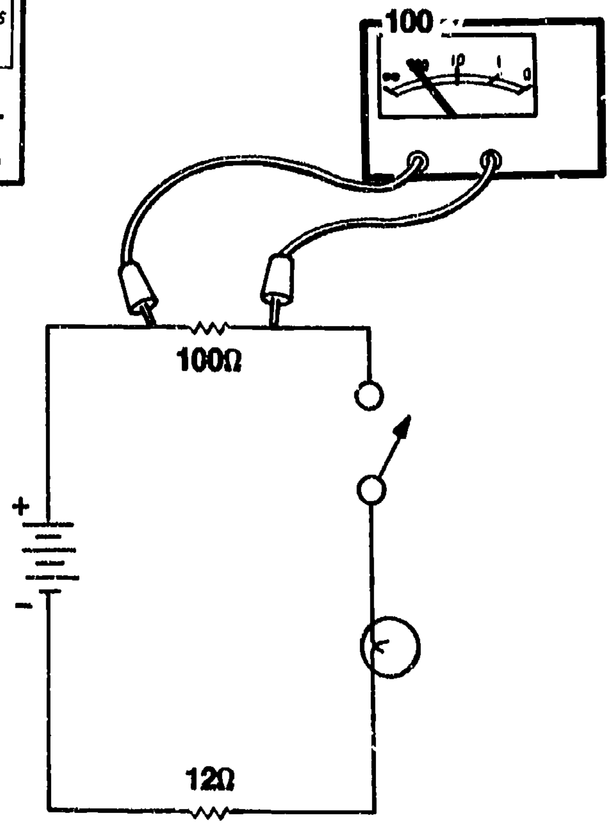


Basic Alternator Operation

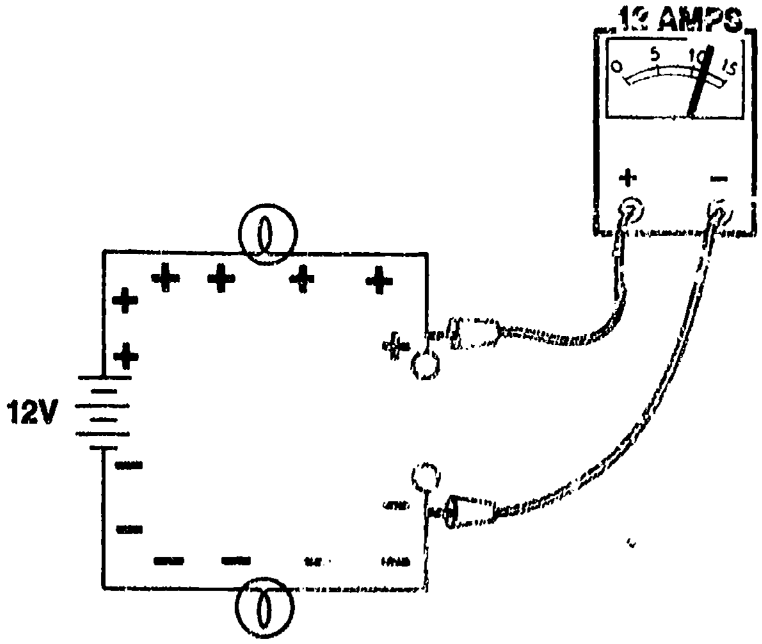
Measuring Instruments



Electric "pressure" is measured in volts with a voltmeter.



Resistance is measured in ohms with an ohmmeter.



Electric current is measured in amperes with an ammeter.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ASSIGNMENT SHEET #1 — SOLVE PROBLEMS USING OHM'S LAW

NAME ______________________________ SCORE ____________

Directions: Read the problems and use the triangle expression of Ohm's Law to solve for the unknown value in each problem.

Example: Cover the unknown in the triangle and solve

(NOTE: E = Voltage; I = Amperes; R = Resistance.)

Show your work on each problem. Turn in to instructor after completion.

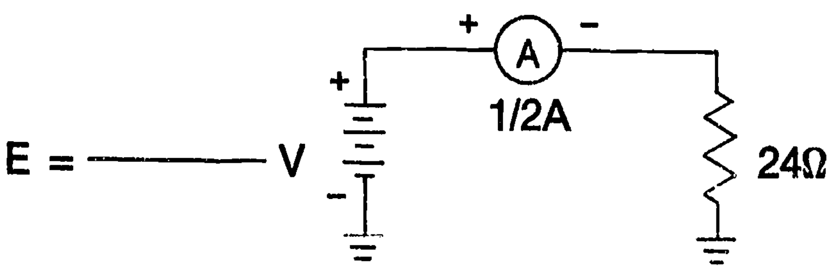
1. The starter of an automobile has a resistance of 0.12 ohms. How much current must a 12.6-volt storage battery supply to start the car?

2. A fan motor in an air conditioner has an internal resistance of 180 ohms. What will be the amperage draw of the motor, on a 12-volt system?

ASSIGNMENT SHEET #1

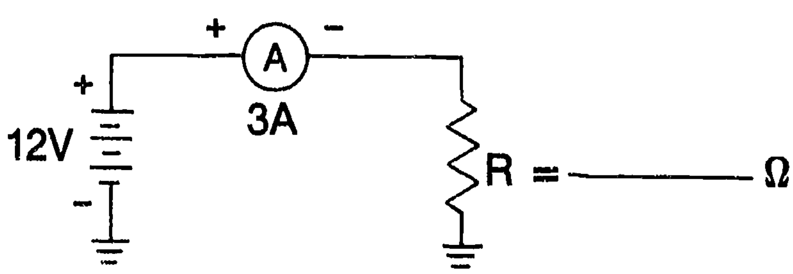
3. Calculate the battery voltage needed to drive a current of 150 amperes through the starter of a car. The starter's resistance is 0.08 ohms.

4. Solve for the unknown voltage.



Circuit with known current and resistance,
but unknown voltage.

5. Solve for the unknown resistance.



Circuit with known voltage and current,
but unknown resistance.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ANSWERS TO ASSIGNMENT SHEET

1. 105 amperes
2. 0.067 amperes
3. 12-volts
4. 12-volts
5. 4-ohms

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

NAME ____________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

(NOTE: Terms and definitions are continued on the following page.)

_____a.	Smallest unit of all matter	1. Alternator
_____b.	Particles with a negative charge in orbit around a core of protons	2. Atom
_____c.	Particles with a positive charge that make up the nucleus of the atom	3. Conductor
_____d.	Flow of electrons through a conductor, measured in amperes	4. Counter emf
_____e.	Any material that permits passage of electric current	5. Current
_____f.	An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator	6. Electrochemical
_____g.	Potential difference that causes flow of current	7. Electromagnet
_____h.	Opposition to current flow in a conductor	8. Electromagnetic induction
_____i.	Material with an extremely high resistance to current flow	9. Electrons
_____j.	Stored chemical energy which can be converted to electrical current	10. Emf
_____k.	Electricity generated by heat	11. Insulator
_____l.	Thermoelectric device used to measure temperature accurately	12. Mutual induction
_____m.	Inducing voltage in a conductor that moves across a magnetic field	13. Parallel circuit

TEST

_____n. Occurs when changing current in one coil induces voltage in a second coil

_____o. Voltage which occurs in a coil when there is a change of current

_____p. Voltage and current produced by a rotating magnetic field cutting across stationary conductors

_____q. Electrical measurement of rate of doing work

_____r. Electromotive force or voltage

_____s. Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

_____t. Current has more than one path to take

_____u. Current has only one path it can take

_____v. A circuit consisting of both series and parallel components

_____w. A wire carrying electric current wound into a coil around an iron core creating a magnetic field

_____x. Voltage loss due to resistance

14. Protons
15. Resistance
16. Self induction
17. Semiconductor
18. Series circuit
19. Series-parallel circuit
20. Thermocouple
21. Thermoelectric
22. Voltage
23. Voltage drop
24. Watt

2. Select true statements concerning safety practices dealing with electrical systems by placing an "X" beside each statement that is true.

_____a. When working on electrical system that is connected to the battery, remove all jewelry.

_____b. When disconnecting battery cables, remove the positive cable first.

_____c. If you are using an ohmmeter, disconnect the battery.

_____d. Never leave the ignition switch on when installing a distributor.

_____e. Never ground the output terminal of the alternator.

_____f. Never lay any conductor across the battery terminals.

_____g. When replacing an electrical component, always disconnect the battery first.

TEST

_____h. Never apply full battery voltage to the fuel tank sending unit.

_____i. When using jumper cables, always connect ground to the frame or engine.

_____j. When using a battery charger, make your connections before plugging the charger in.

_____k. When adding accessories, make sure they match the vehicle's ground.

_____l. When replacing a conductor, always use the same size (gauge) conductor.

_____m. When adding accessories, be sure not to exceed the charging system output.

3. Name two particles found in an atom.

   a. ____

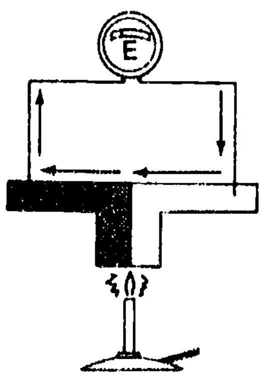
   b. ____

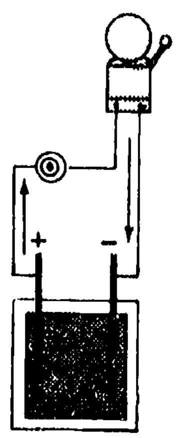
4. Define electricity according to the atomic theory.

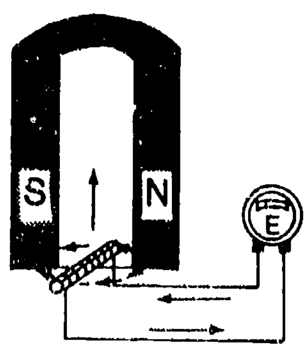
   ____

   ____

5. Identify three sources of electricity related to diesel engines.







a. ____________________ b. ____________________ c. ____________________

TEST

6. Name three parts of a basic circuit.

   a. ____________________

   b. ____________________

   c. ____________________

7. Distinguish between conductors and insulators of electricity by placing a "C" in front of the items that are conductors and an "I" in front of the insulators.

   _____a. Mercury

   _____b. Brass

   _____c. Rubber

   _____d. Glass

   _____e. Wood

   _____f. Nickel

   _____g. Plastic

   _____h. Nichrome

   _____i. Silver

   _____j. Gold

   _____k. Ceramic

   _____l. Aluminum

8. Explain why copper is widely used as a conductor.

   ____

9. Match the basic circuit terms on the right with their units of measure.

_____a.	Volts	1. Current
_____b.	Ohms	2. Voltage
_____c.	Amperes	3. Resistance

TEST

10. Match the basic electrical schematic symbols with their correct names.

(NOTE: Schematic symbols and names are continued on the following page.)

_____a. 

_____b. 

_____c. 

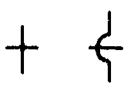
_____d. 

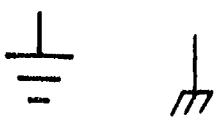
_____e. 

_____f. 

_____g. 

_____h. 

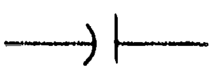
_____i. 

_____j. 

_____k. 

_____l. 

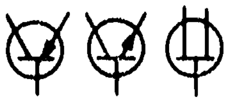
_____m. 

_____n. 

1. Ammeter
2. Battery
3. Cable — not connected
4. Circuit breaker
5. Condenser or capacitor
6. Connection
7. Connectors — separable, engaged
8. Diode
9. Direction of current
10. Double-throw switch
11. Fuse
12. Fusible link or wire
13. Ground
14. Inductor (coil)

TEST

_____ o. 

_____ p. 

_____ q. 

_____ r. 

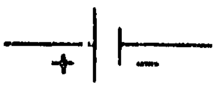
_____ s. 

_____ t. 

_____ u. 

_____ v. 

_____ w. 

_____ x. 

_____ y. 

_____ z. 

_____ aa.

15. Inductor (solenoid)
16. Lamp
17. Negative terminal
18. Ohms of resistance
19. Positive terminal
20. Resistance or load
21. Switch — single throw
22. Temperature or fuel gauge
23. Termination
24. Transistor
25. Variable resistance
26. Voltage limiter
27. Voltmeter

TEST

11. Match the letter designations used in Ohm's Law with the correct terms.

_____a.	Electromotive force in volts	1. R
_____b.	Intensity (current) in amps	2. I
_____c.	Resistance in ohms	3. E

12. Draw Ohm's Law formula in triangle expression.

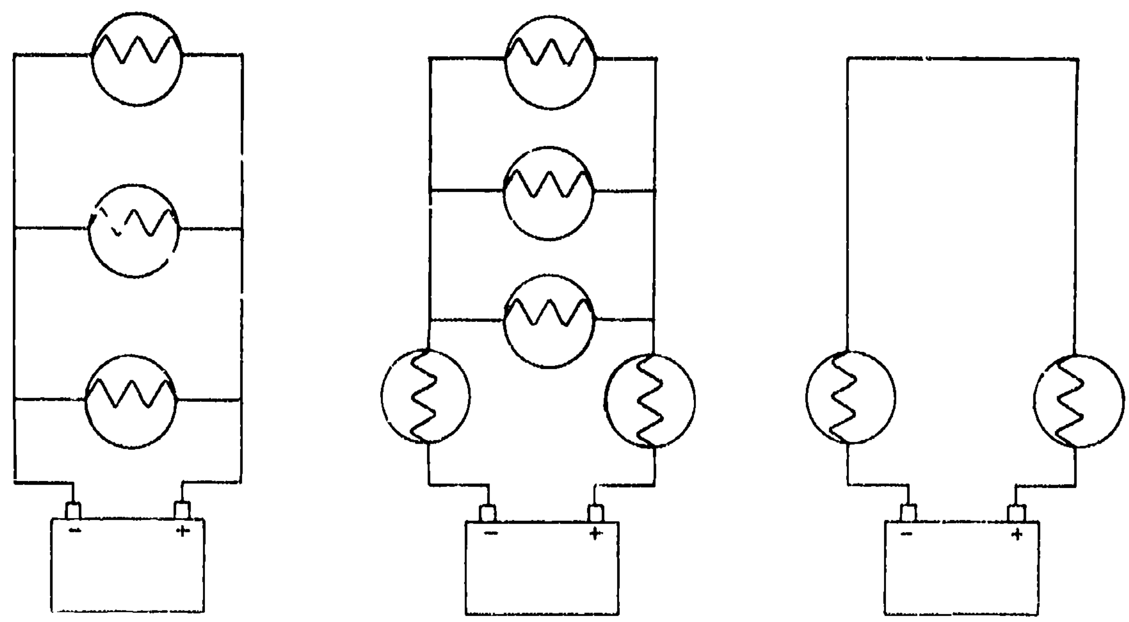
13. State Ohm's Law in letter formula.

a. ________________________________

b. ________________________________

c. ________________________________

14. Identify three types of electrical circuits.



a. ____________ b. ____________ c. ____________

TEST

15. Name three factors affecting resistance in a conductor.

    a. ______________________________

    b. ______________________________

    c. ______________________________

16. Select from the following list characteristics of magnetism by placing an "X" beside each characteristic.

    _____a. Every magnet has a north and south pole.

    _____b. Like poles attract and unlike poles repel.

    _____c. Magnetic materials are acted upon when located in a field of force.

    _____d. Every magnet has a field of force surrounding it.

    _____e. Unlike poles attract and like poles repel.

17. Select true statements concerning the relationship between electricity and magnetism by placing an "X" beside each statement that is true.

    _____a. Current passed through a wire creates a magnetic field around the wire.

    _____b. Magnetic lines never change direction when the current flow changes direction.

    _____c. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate.

18. Select true statements concerning electromagnetic induction by placing an "X" beside each statement that is true.

    _____a. Conductor moving across a magnetic field will have a voltage (emf) induced in it.

    _____b. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force.

19. List three ways to induce voltage by electromagnetic induction.

    a. ______________________________

    b. ______________________________

    c. ______________________________

TEST

20. List three factors that determine the magnitude of induced voltage.

    a. ____________________

    b. ____________________

    c. ____________________

21. Name two types of electric current.

    a. ____________________

    b. ____________________

22. Distinguish between direct and alternating current by placing "DC" in front of the items that refer to direct current and "AC" in front of the items that refer to alternating current.

    _____a. Flows in one direction then reverses and flows in the opposite direction

    _____b. Dry cell battery

    _____c. Supplied by an alternating current generator (alternator)

    _____d. Flows in one direction only

    _____e. Supplied by a generator

23. Name three instruments used in checking electrical circuits.

    a. ____________________

    b. ____________________

    c. ____________________

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

24. Solve problems using Ohm's Law. (Assignment Sheet #1)

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ANSWERS TO TEST

1.

a.	2	i.	11	q.	24
b.	9	j.	6	r.	10
c.	14	k.	21	s.	4
d.	5	l.	20	t.	13
e.	3	m.	8	u.	18
f.	17	n.	12	v.	19
g.	22	o.	16	w.	7
h.	15	p.	1	x.	23

2. a, c, d, e, f, g, h, j, k, l, m

3. a. Electron
   b. Proton

4. The flow of electrons from atom to atom in a conductor

5. a. Thermoelectric
   b. Electrochemical
   c. Electromagnetic

6. Any three of the following:
   a. Voltage
   b. Resistor
   c. Conductor
   d. Control device

7.

a.	C	g.	I
b.	C	h.	C
c.	I	i.	C
d.	I	j.	C
e.	I	k.	I
f.	C	l.	C

8. Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties.

9. a. 2
   b. 3
   c. 1

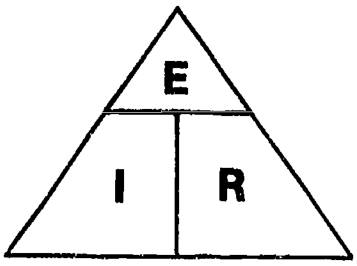
10.

a.	20	h.	22	o.	26	v.	14
b.	19	i.	3	p.	24	w.	15
c.	25	j.	13	q.	18	x.	2
d.	7	k.	4	r.	9	y.	21
e.	16	l.	8	s.	6	z.	23
f.	10	m.	11	t.	27	aa.	17
g.	1	n.	5	u.	12		

ANSWERS TO TEST

11. a. 3
    b. 2
    c. 1

12.



13. a. $E = I \times R$
    b. $I = E/R$
    c. $R = E/I$

14. a. Parallel
    b. Series-parallel
    c. Series

15. a. Length of wire
    b. Diameter of wire
    c. Temperature of wire

16. a, c, d, e

17. a, c

18. a, b

19. a. Generated voltage by relative motion
    b. Self induction voltage created by a change of current in the conductor
    c. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

20. a. Strength of the magnetic field
    b. Speed at which lines of force are cutting across the conductor
    c. Number of conductors that are cutting across the lines of force

21. a. Direct
    b. Alternating

22. a. AC
    b. DC
    c. AC
    d. DC
    e. DC

ANSWERS TO TEST

23. a. Ammeter
    b. Voltmeter
    c. Ohmmeter

24. Evaluated to satisfaction of instructor

ELECTRICAL CIRCUITS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to read a wiring diagram, check circuits, install wire terminals, and splice a wire. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical circuits with their correct definitions.
2. Calculate voltage drop across resistors in a series circuit.
3. Calculate current in a parallel circuit.
4. Calculate current in a series-parallel circuit.
5. Match the basic electrical circuit failures with the correct causes.
6. Select true statements concerning voltage drop.
7. Name ıree types of circuit protection.
8. Complete statements concerning selection of cable for rewiring needs.
9. Select from a list characteristics of a wiring diagram.
10. Label parts of a circuit identification code.

OBJECTIVE SHEET

11. Match types of connectors with their correct names.

12. Arrange in order the steps in troubleshooting electrical systems.

13. Read a wiring diagram. (Assignment Sheet #1)

14. Demonstrate the ability to:

    a. Check voltage. (Job Sheet #1)

    b. Check a circuit for an open. (Job Sheet #2)

    c. Install a soldered terminal. (Job Sheet #3)

    d. Install a solderless terminal. (Job Sheet #4)

    e. Splice a wire (solder method). (Job Sheet #5)

ELECTRICAL CIRCUITS
UNIT II

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets and handout.

F. Discuss information and assignment sheets and handout.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Take a field trip to a shop where electrical work is performed.
2. Make a circuit board of a simple lighting system.
3. Have students draw wiring diagrams.
4. Demonstrate safety practices on electrical systems.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Armstrong, Ivan J. *Auto Mechanics*. Vol. II. Stillwater, OK: State Department of Vocational and Technical Education, 1978.

B. Foutes, William A. *Diesel Mechanics: Electrical Systems*. Stillwater, OK: Department of Vocational and Technical Education, 1982.

C. *Fundamentals of Service: Electrical Systems*, 4th ed. Moline, IL: Deere & Company, 1979.

D. Schulz, Erich J. *Diesel Mechanics*. 2nd ed. New York: Gregg Division, McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

Text

Chilton's Guide to Electronic Engine Controls Manual
Teaching Aids Incorporated
Order #CH 7535
Box 1798
Costa Mesa, CA 92628-0798
1-800-345-1214

ELECTRICAL CIRCU
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. Cable — Stranded conductor usually covered with insulating material

B. Circuit — Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source

C. Continuity ligh' — A self powered light, used to check for open circuits

(CAUTION: Do not hook into live circuit.)

D. Crimping tool — A tool used to crimp terminals to wires

E. Double filament bulb — Bulb with two lighting elements

F. Gauge — Determines the diameter and the capacity of a wire or cab'e

(NOTE: The heavier the wire, the smaller the gauge number.)

G. Ground — Uninsulated side of a circuit which is in a vehicle

H. Integrated circuit (IC) — Sealed unit containing resistors, diodes, and transistors

I. Junction block — A multiple connection point for current or ground which can also be used as a test point

J. Jumper wire — Wire, usually with alligator clips, that is used to provide current or ground to an electrical device

K. Polarity — Refers to the grounded battery terminal or to an electrical circuit or to the north and south pole of a magnet

L. Single filament bulb — Bulb with only one lighting element

M. Solder — A tin lead alloy with a low melting point; used to fuse electrical connections

N. Soldering iron — A tool that delivers high temperatures; used to melt solder

O. Switch — A device that opens and closes a circuit

P. Terminal — Type of screw, post, p· ·, or socket at the end of a wire or cable

Q. Test light — A test instrument used to find current flow

INFORMATION SHEET

R. Wiring diagram (schematic) — Drawing that uses electrical symbols and lines to show electrical circuits

S. Wiring harness — Any system of wires which are taped together for electrical distribution throughout the vehicle

II. **Rules for series circuits** (Transparency 1)

A. Current through each resistor is the same.

B. Voltage drops across each resistor will be different if the resistance values are different.

C. Sum of the voltage drops equals the source voltage.

III. **Rules for parallel circuits** (Transparency 2)

A. Voltage across each resistor is the same.

B. Current through each resistor will be different if the resistance values are different.

C. Sum of the separate currents equals the total circuit current.

IV. **Rules for series-parallel circuits** (Transparency 3)

A. Current in the circuit is equal to the total voltage divided by the total resistance.

(NOTE: Two resistors in a parallel circuit equal the product divided by the sum.)

Example: $\frac{6 \times 3}{6 + 3} = 2$ ohms

B. The resistor in series is calculated first, leaving the remaining voltage equally distributed across the resistors in parallel.

C. Sum of the separate currents in the parallel resistors equals the total circuit current.

V. **Basic electrical circuit failures** (Transparency 4)

A. Open circuit — Break in an electrical circuit which causes extremely high resistance

(NOTE: Usually, no current will flow through an open circuit.)

B. Shorted circuit — Unwanted connection, usually copper to copper, that allows current to bypass all or part of the circuit

INFORMATION SHEET

C. Grounded circuit — Unwanted connection that bypasses all or part of the circuit from the insulated side to the grounded side of the circuit

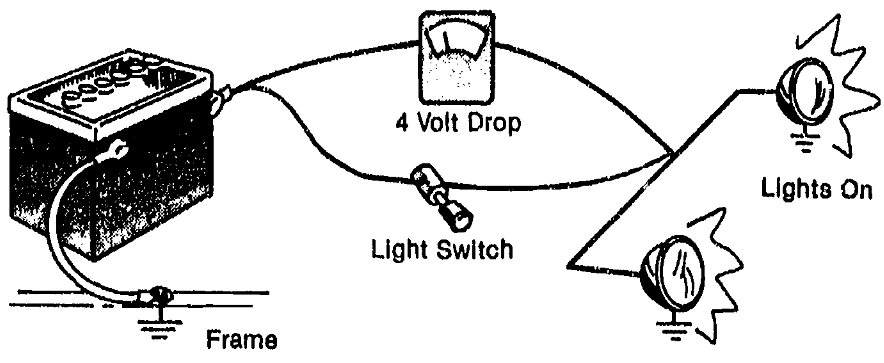
(NOTE: A grounded circuit is usually a copper-to-iron connection.)

D. High resistance circuit — Failure caused by poor or corroded connections or damaged wires which reduces current flow in the circuit

VI. **Voltage drop**

A. Voltage drop occurs when electricity flows through a resistance.

B. Voltage drop can be measured directly by connecting the voltmeter across the component with the circuit operating.



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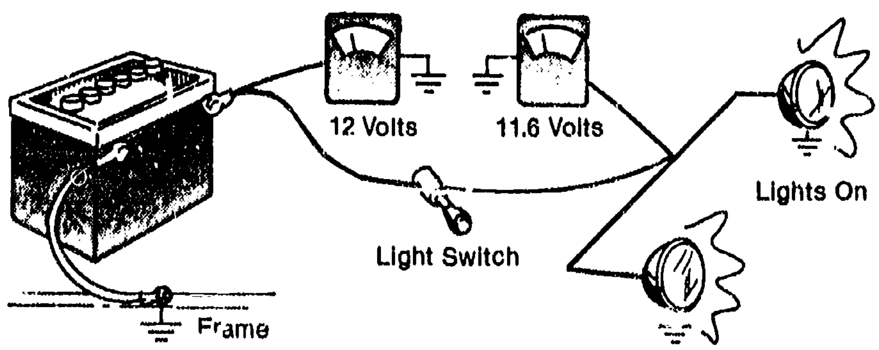
(NOTE: To determine if there is high resistance, compare voltmeter reading against specifications.)

C. Voltage drop can be measured by connecting a voltmeter on each end of the component or wire to ground.

(NOTE: The difference between the two readings is the voltage drop.)



12 volts − 11.6 volts = .4 volt drop

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(NOTE: This method is used on long wires where the voltmeter leads are too short.)

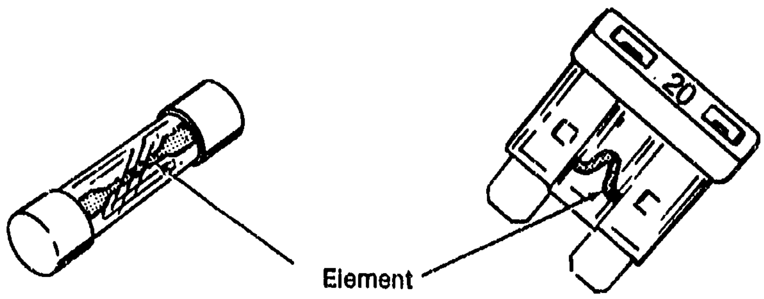
D. Voltage drop adds up when connected in series with the load.

INFORMATION SHEET

VII. Types of circuit protection

A. Fuses

(NOTE: Each type fuse has a metal element that is designed to melt (or blow) at a specific current level, opening the circuit and protecting it from damage.)



Typical fuses used in an automotive circuit

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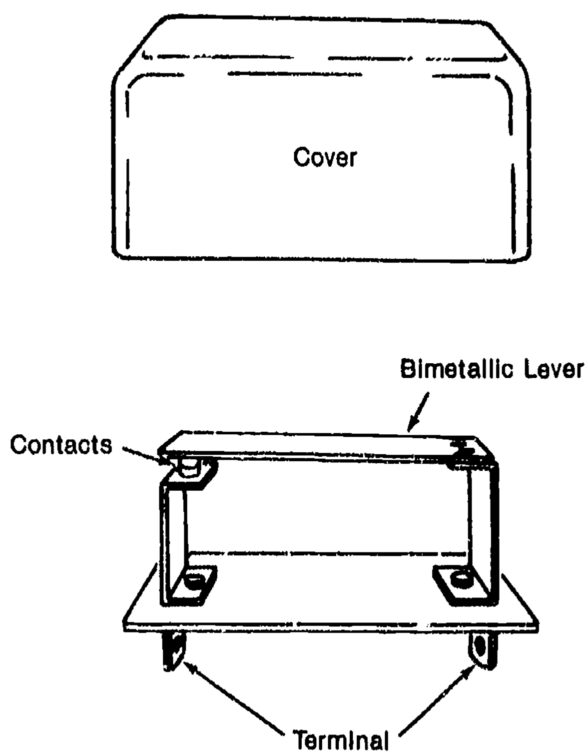
B. Circuit breaker

(NOTE: The circuit offers protection equal to a fuse with the added benefit that it can be used again. Rather than burn open, it has a set of contacts that open when its current rating is exceeded.)



Circuit breaker construction

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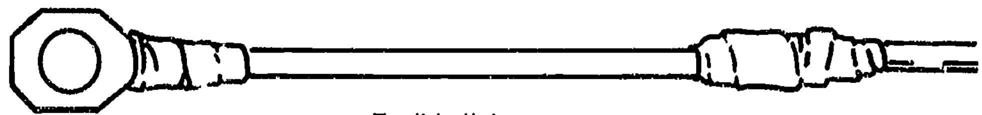
INFORMATION SHEET

C. Fusible links

(NOTE: A fusible link is a short piece of wire that is smaller in diameter than the wire it is connected to. Should a short occur, the link will burn open long before the larger circuit, protecting the rest of the circuit.)



Fusible link

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VIII. Selection of cable for various rewiring needs

A. Cable should be of proper gauge size to handle maximum required electrical loads. (Handout #1)

B. Cable should feature insulating and covering materials which provide the longest cable life possible.

IX. Characteristics of a wiring diagram (Transparency 5, Assignment Sheet #1)

(NOTE: Reading a wiring diagram is something like reading a road map. A road map shows routes that connect one place with another; a wiring diagram shows routes, too. The lines represent actual wires, which are identified by numbers much like highways are identified on a road map.)

A. Lines represent wires.

B. Wires have identification numbers.

C. Wires are color-coded.

D. Components are represented by symbols.

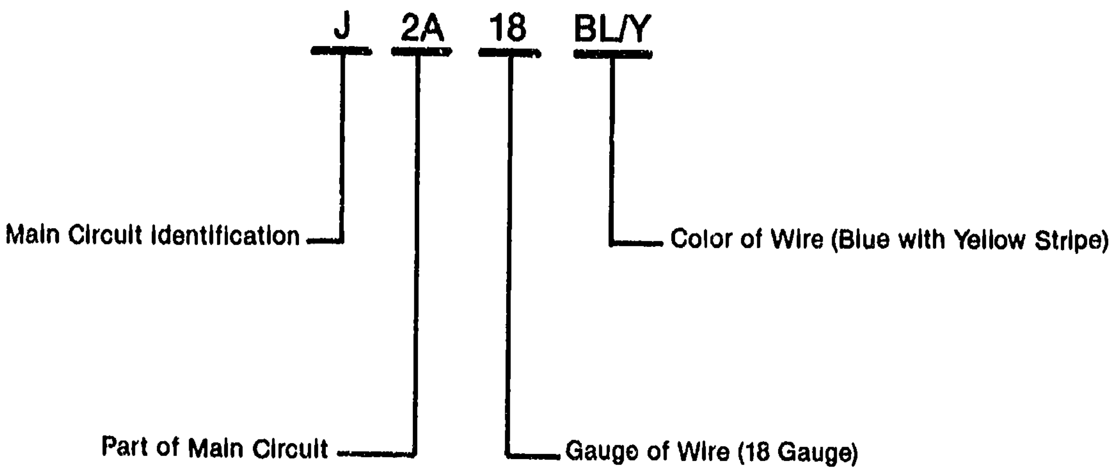
E. Symbols indicate locations of circuits or components in the vehicle.

F. Wiring diagrams are needed by all mechanics.

(NOTE: Because of the constant change in electrical requirements, even experienced mechanics have to rely on wiring diagrams.)

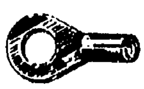
INFORMATION SHEET

X. Parts of a typical circuit identification code

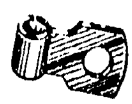


XI. Types of connectors

A. Ring (eyelet)

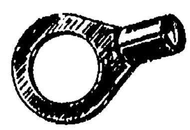


B. Roll

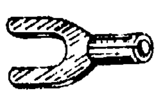


C. Female snap on

D. Lug



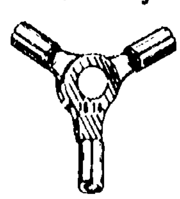
E. Slotted-flange bay



F. Insulated butt

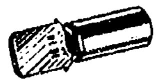
G. Slotted hook

H. Three way



INFORMATION SHEET

I. Male slide



J. Female slide

K. Male plug (bullet)

L. Female plug (bullet connector)

XII. **Steps in troubleshooting electrical systems**

A. Know the syste ...

Example: Study service manual and service bulletins.

B. Ask the operator.

(NOTE: Often a passing comment by the operator may provide the key to the problem.)

C. Inspect the system.

(NOTE: Many times the problem can be detected without turning on the switch or starting the machine.)

Inspection Checklist — Electrical

	Yes	No
Bare wires or shorts	☐	☐
Loose wires or opens	☐	☐
Poor connections	☐	☐
Battery electrolyte level	☐	☐
Generating belt tension	☐	☐
Overheated components	☐	☐
Other trouble signs	☐	☐

D. Operate the machine if possible.

(NOTE: Operate all electrical circuits and look for sparks or smoke which might indicate the trouble.)

E. List the possible causes.

INFORMATION SHEET

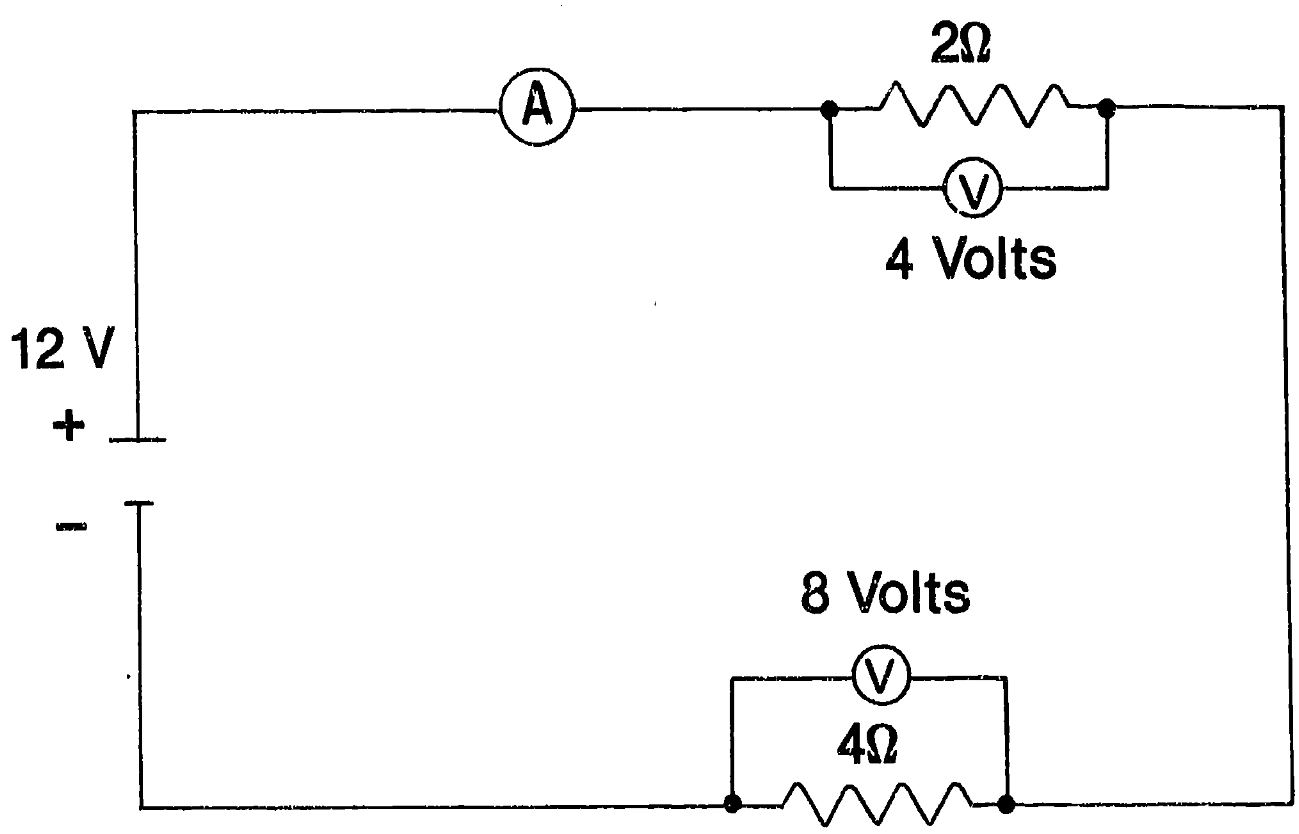
F. Reach a conclusion.

(NOTE: Scan your list of possible causes to determine the most likely causes and those which are easiest to verify.)

G. Test your conclusion.

(NOTE: Guessing is time-consuming and expensive.)

Series Circuit Rules

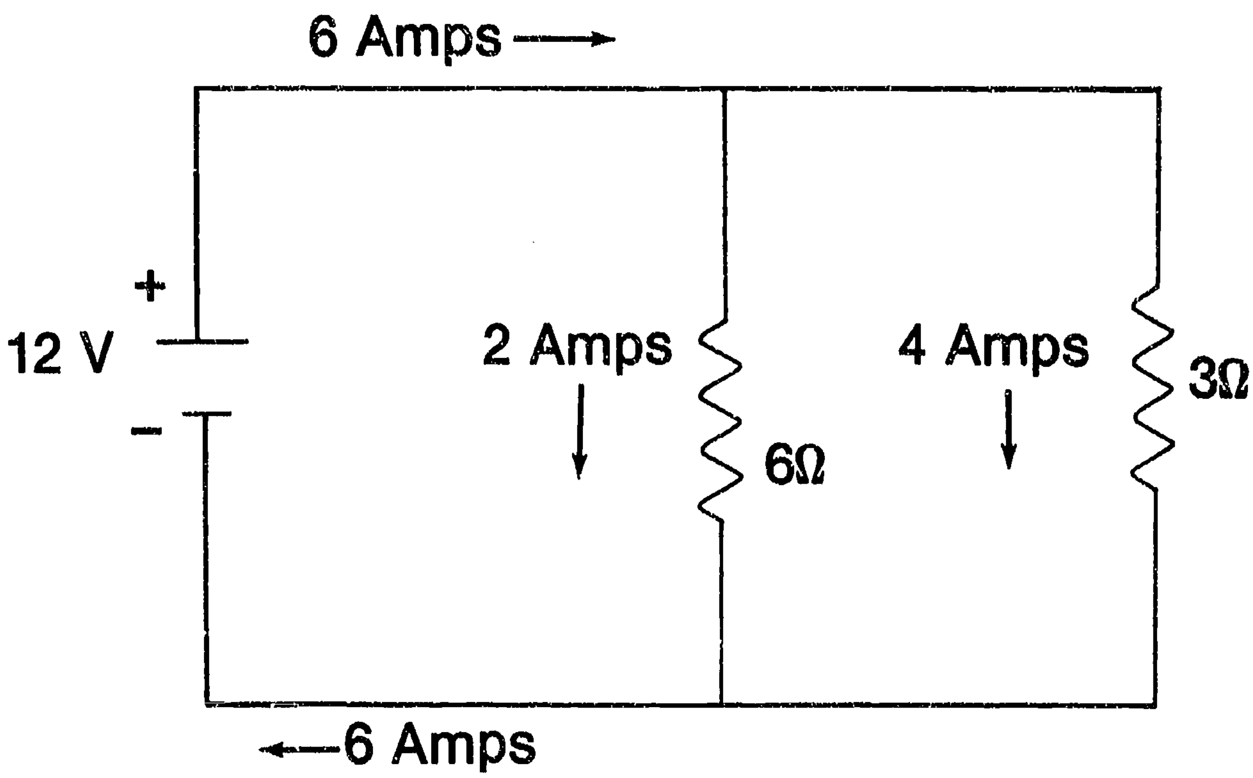


A. I = E/R'I
= 12/6 = 2 Amperes

B. E = IR
E = 2 × 2 = 4 Volts
E = 2 × 4 = 8 Volts

C. 4 + 8 = 12 Volts

Parallel Circuit Rules

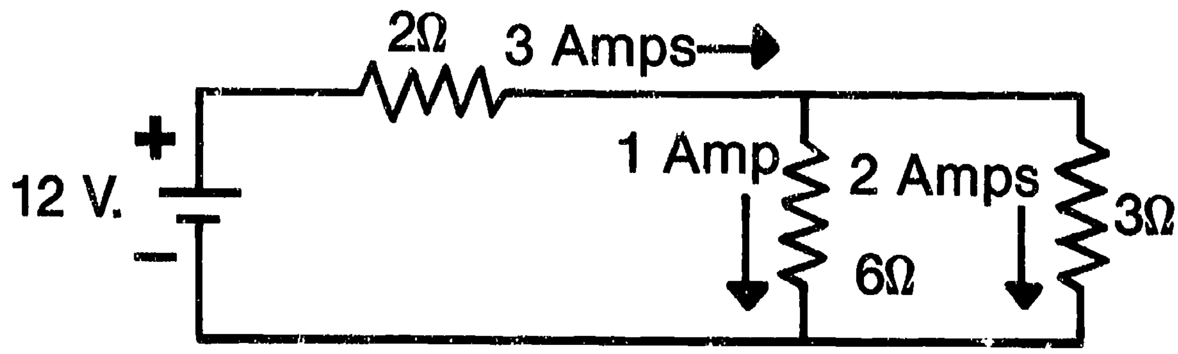


A. Battery voltage across each resistor = 12 Volts

B. I = E/R = 12/6
= 2 Amperes
I = E/R = 12/3
= 4 Amperes

C. I = 6 Amps R = E/I
= 12/6 = 2 Ohms

Series-Parallel Circuit Rules



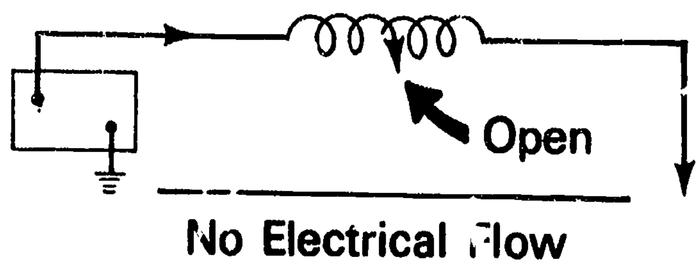
Series-Parallel Circuit

A. Resistors in parallel — 2 ohms
Resistor in series — 2 ohms
Total resistance — 4 ohms
i = 12/4 = 3 amps

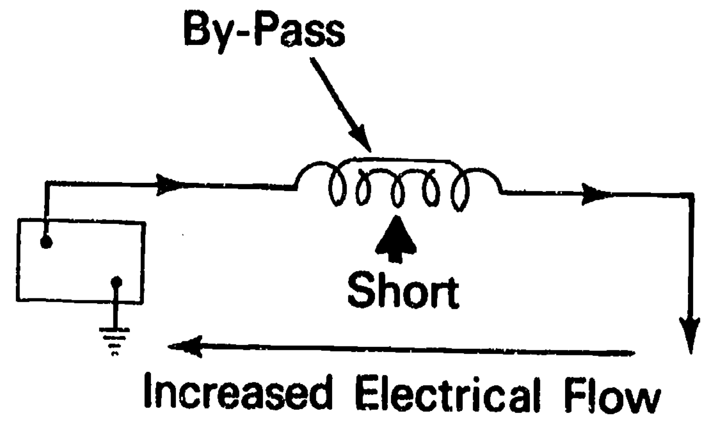
B. Resistor in series
E = IR = 3 × 2 = 6 volts
Resistor in parallel
12 − 6 = 6 volts

C. 6 ohm resistor
I = E/R = 6/6 = 1 amp
3 ohm resistor
I = E/R = 6/6 = 2 amps

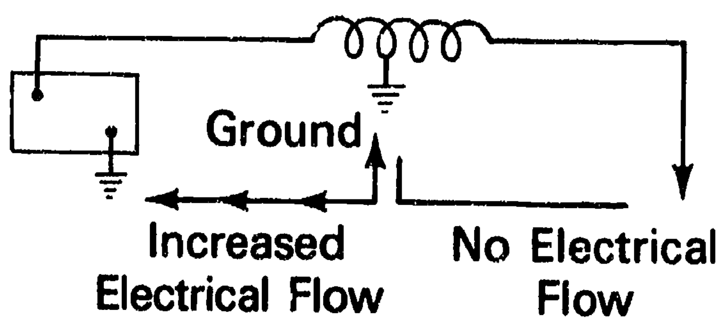
Causes of Electrical Failures



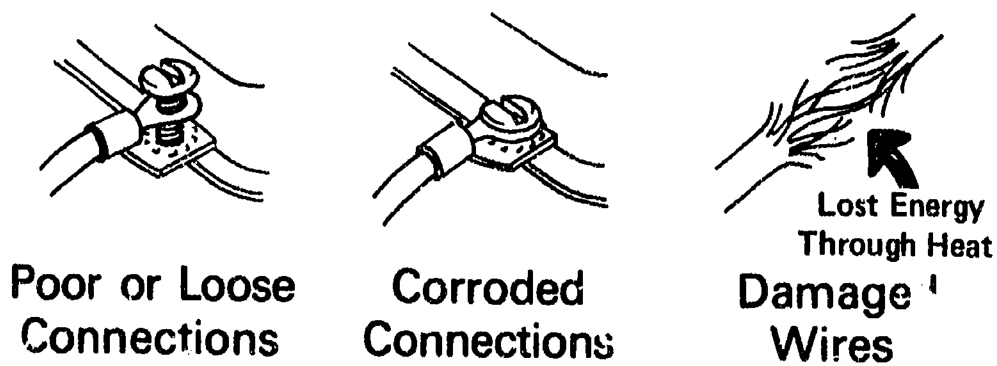
Open Circuit



Shorted Circuit

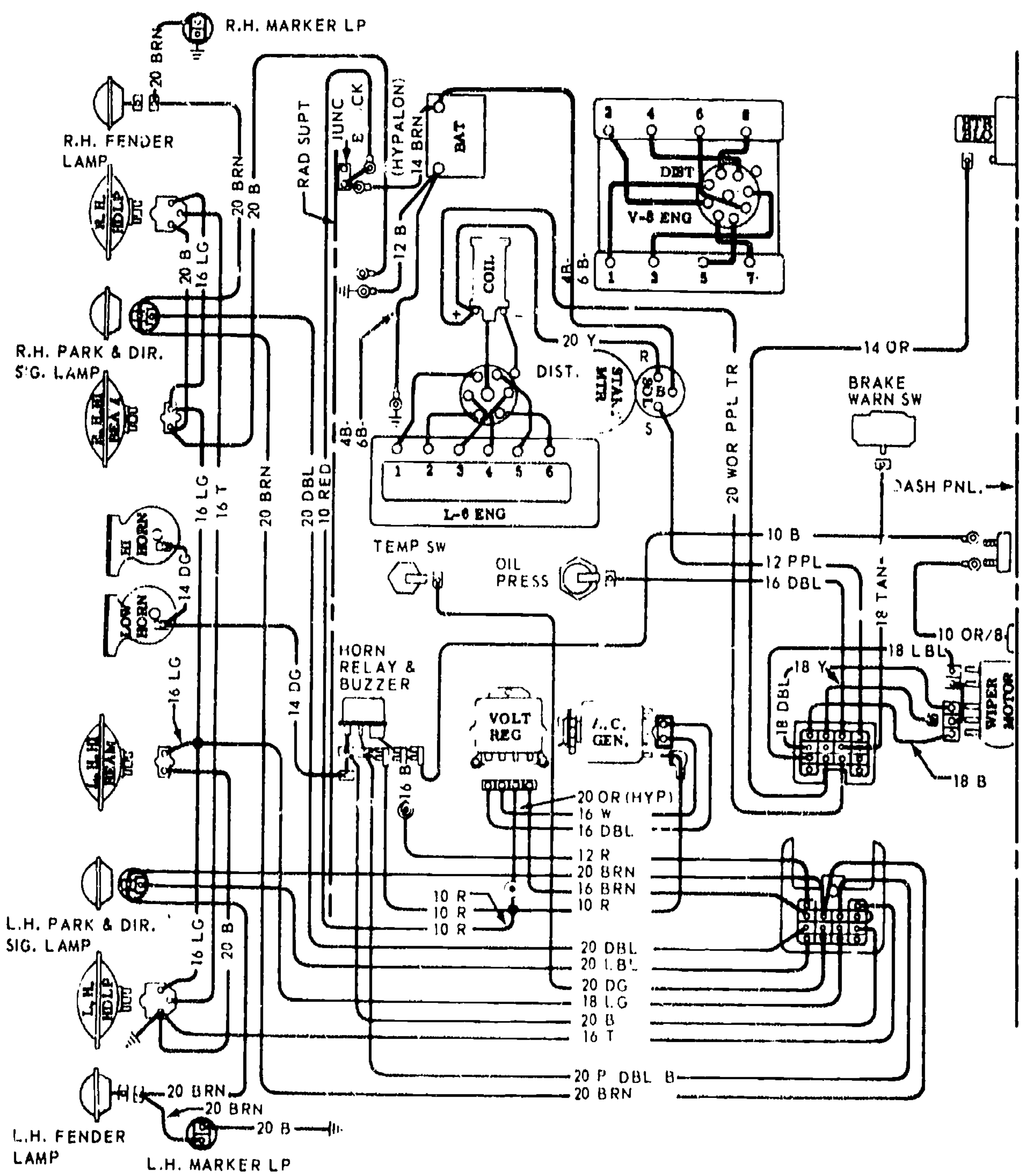


Grounded Circuit



High Resistance Circuit

Typical Engine Compartment Wiring Diagram



(Courtesy of Chevrolet Motor Division of General Motors Corporation)

ELECTRICAL CIRCUITS
UNIT II

HANDOUT #1 — WIRE GAUGE RECOMMENDATIONS

TRACTOR CIRCUITS

Cable gauge recommendations for rewiring

CIRCUIT	12-Volt Gauge	6-Volt Gauge
AMMETER TO:		
Starter Motor	12	10
Ignition Switch	12	10
Light Switch	12	10
Voltage Reg. (Batt.)	12	10
Horn Relay		10
BACK-UP LAMP	16	14
BATTERY CABLES (See Note Below)		
COIL TO:		
Ignition Switch	16	14
Distributor	16	14
CIGAR LIGHTER	16	14
CLOCK	16	18
DIMMER SWITCH TO:		
Light Switch	14	12
Low Beam Head Lamp	16	14
High Beam Head Lamp	14	12
High Beam Indicator	18	16
DIRECTIONAL SIGNAL SWITCH TO:		
Flasher	18	14
Left Turn Signal Lamps	16	14
Right Turn Signal Lamps	16	14
Stop Lamp Switch	16	14
DOME LAMP TO:		
Feed	18	16
Switch	18	18
Ground	18	16
DIRECTIONAL SIGNAL		
FLASHER TO:		
Ignition	18	18
Direction Indicator Lamps	18	18
FUEL (GAS) GAUGE TO:		
Ignition	18	18
Sending Unit	16	18

CIRCUIT	12-Volt Gauge	6-Volt Gauge
GENERATOR TO:		
Regulator (Armature)	12	10
Regulator (Field)	12	10
Ground (Regulator)	.3	16
HEAD LAMPS TO:		
Ground	18	16
HEATER		
HORN RELAY TO:		
Feed	12	10
Horn	12	10
Switch	18	16
LIGHT SWITCH TO:		
Parking Lights	18	16
Tail Lamps	16	14
License Lamp	18	16
Instrument Lights	18	16
Stop Light Switch	16	14
OIL PRESSURE GAUGE TO:		
Feed	18	16
Sending Unit	18	16
RADIO		
REAR SEAT SPEAKER	18	16
SPARK PLUG CABLE		
SPOT LAMP	16	14
STARTER SWITCH TO SOLENOID	12	10
TEMPERATURE GAUGE TO:		
Ignition	18	16
Sending Unit	16	16
TRAILER-CONNECTOR CORD:		
7 Conductor	(6/12 and 1/10)	
6 Conductor	16	14
4 Conductor	16	14
TRUNK LAMP	16	14
UNDER HOOD LAMP	16	14

NOTE: Battery Cable — Ampere draw of starter motor depends on many factors. It is advisable to use the same size cable recommended by the vehicle manufacturer.

Tractor and Trailer Ampere and Candlepower Requirements

ELECTRICAL UNIT	12-VOLT UNITS			6-VOLT UNITS		
	Maximum Amperes	Design Voltage	Candlepower or Watts	Maximum Amperes	Design Voltage	Candlepower or Watts
Clearance and Marker Lamps	.5	12.5	3	.7	7.0	3
Coil	4.5	–	–	4.5	–	–
Directional Signal Lamps	2.1	12.8	32	3.0	6.4	21
Dome Lamps	1.0	12.8	15	2.0	6.5	15
Gas Gauge	.2	14.5	–	.3	7.2	–
Head Lamps — Upper	4.2	12.6	50 Watts	7.4	6.4	45 Watts
— Lower	3.4	12.8	40 Watts	5.6	6.4	45 Watts
Horn	7.0	–	–	10.0	.	.
Instrument Lamp	.3	14.0	2	.5	7.0	2
License Lamp	.5	12.5	3	.7	7.0	3
Parking Lamps	.6	14.0	4	.9	7.0	3
Spot Lamp	2.6	12.8	30 Watts	4.3	6.2	30 Watts
Stop Lamp	2.1	12.8	32	3.0	6.4	21
Tail Lamp	.6	14.0	4	.9	7.0	3

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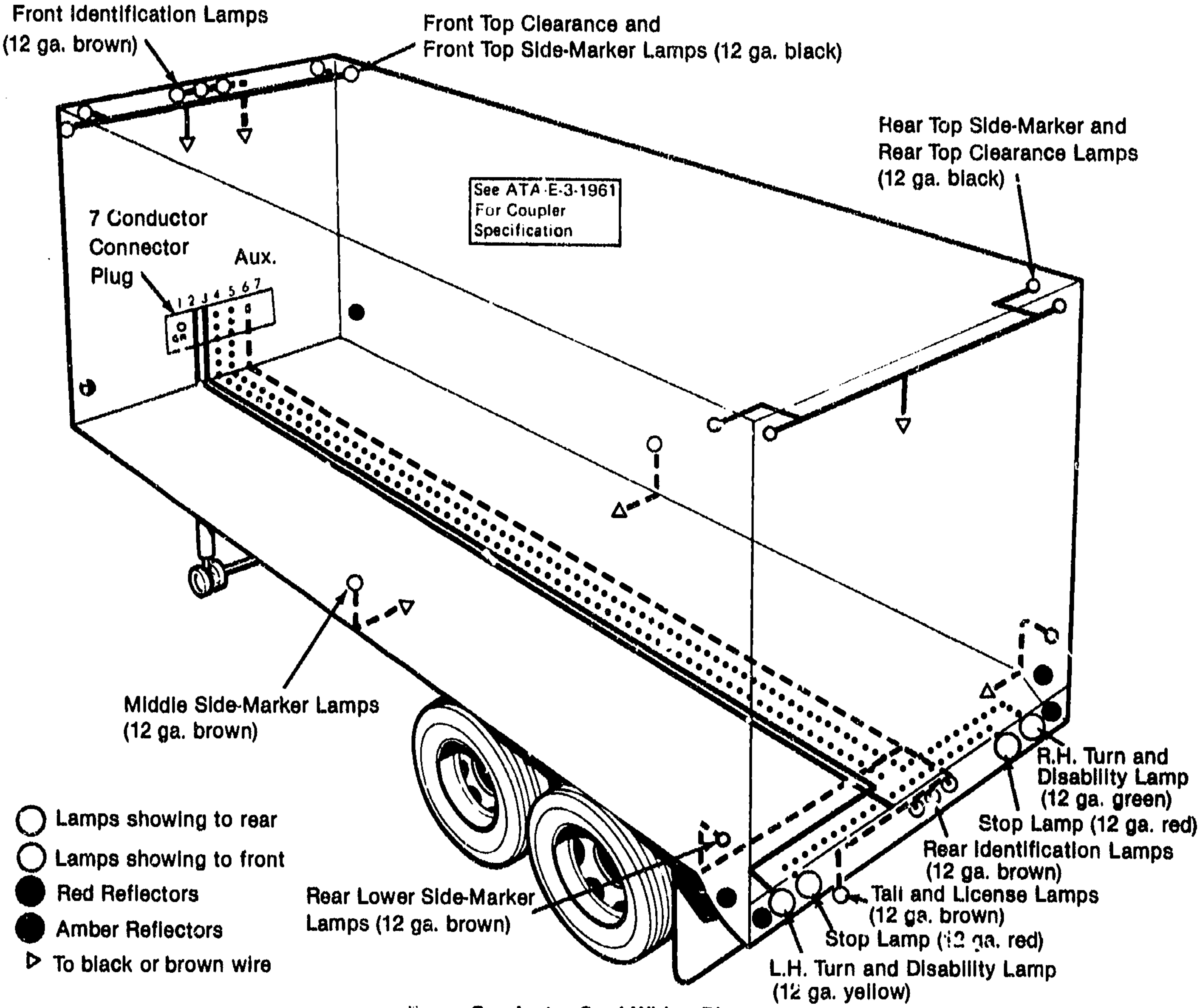
HANDOUT #1



Seven Conductor Cord Wiring Diagram

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DELCO CABLE NUMBERS FOR TRAILER WIRING

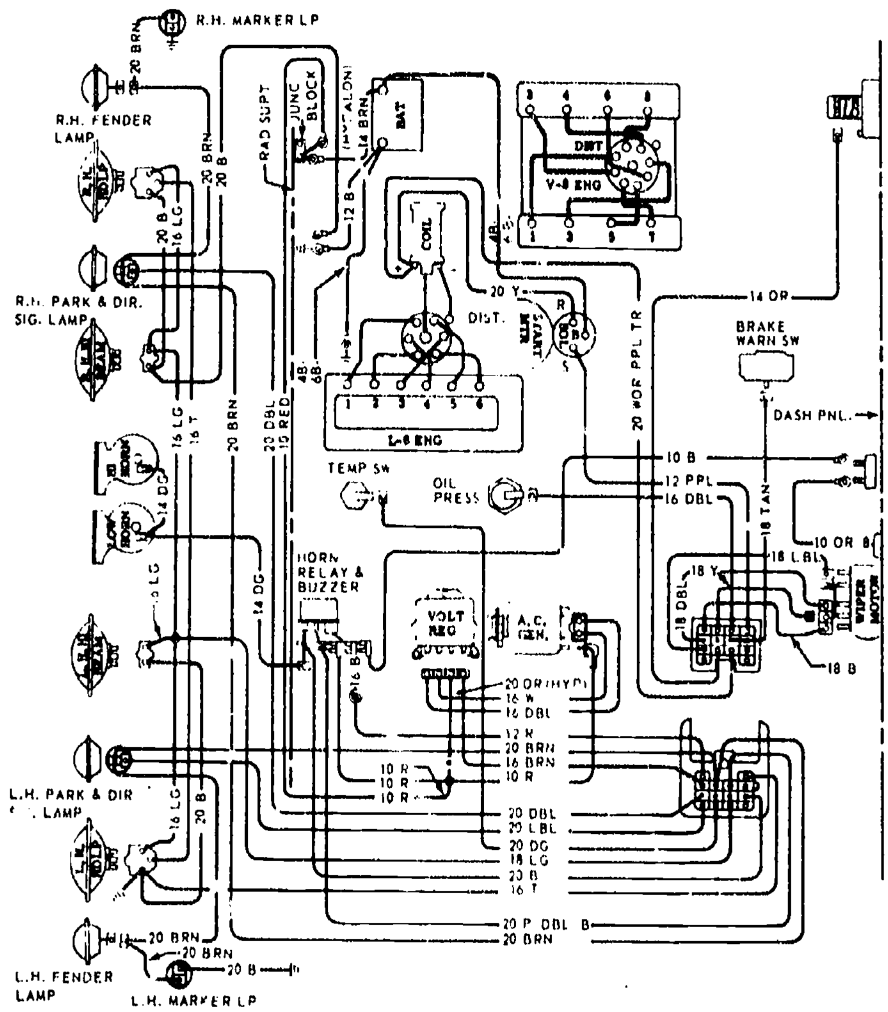
12-Gauge Cable				
Connector Pin No.	Code	Color	Plastic Covered	Insulex
6	▬ ▬ ▬ ▬ ▬ ▬	Brown	954	812X
2	▬▬▬▬▬▬	Black	954-B	812-BX
5	• • • • • • • • • •	Green	954-G	812-GX
4	• • • • • • • • • •	Red	954-R	812-RX
7	▬ ▬ ▬ ▬ ▬	Blue	954-U	812-UX
3	▬▬▬▬▬▬	Yellow	954-Y	812-YX
1	▬▬▬▬▬▬	White	954-W	812-WX

ELECTRICAL CIRCUITS
UNIT II

ASSIGNMENT SHEET #1 — READ A WIRING DIAGRAM

NAME ______________________________ SCORE ____________

Wiring Diagram



(Courtesy of Chevrolet Motor Division of General Motors Corporation)

Directions: Use the wiring diagram to complete the questions below. List the wire size and color for the following components.

	Gauge of Wire	Color of Wire
1. Temperature sender switch	________	________
2. Oil pressure sender switch	________	________
3. Alternator battery wire	________	________
4. Headlight ground wire	________	________
5. Heater blower motor feed wire	________	________

ELECTRICAL CIRCUITS
UNIT II

ANSWERS TO ASSIGNMENT SHEET

1.	20 gauge	Dark green
2.	16 gauge	Dark blue
3.	10 gauge	Red
4.	20 gauge	Black
5.	14 gauge	Orange

ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #1 — CHECK VOLTAGE

A. Tools and materials

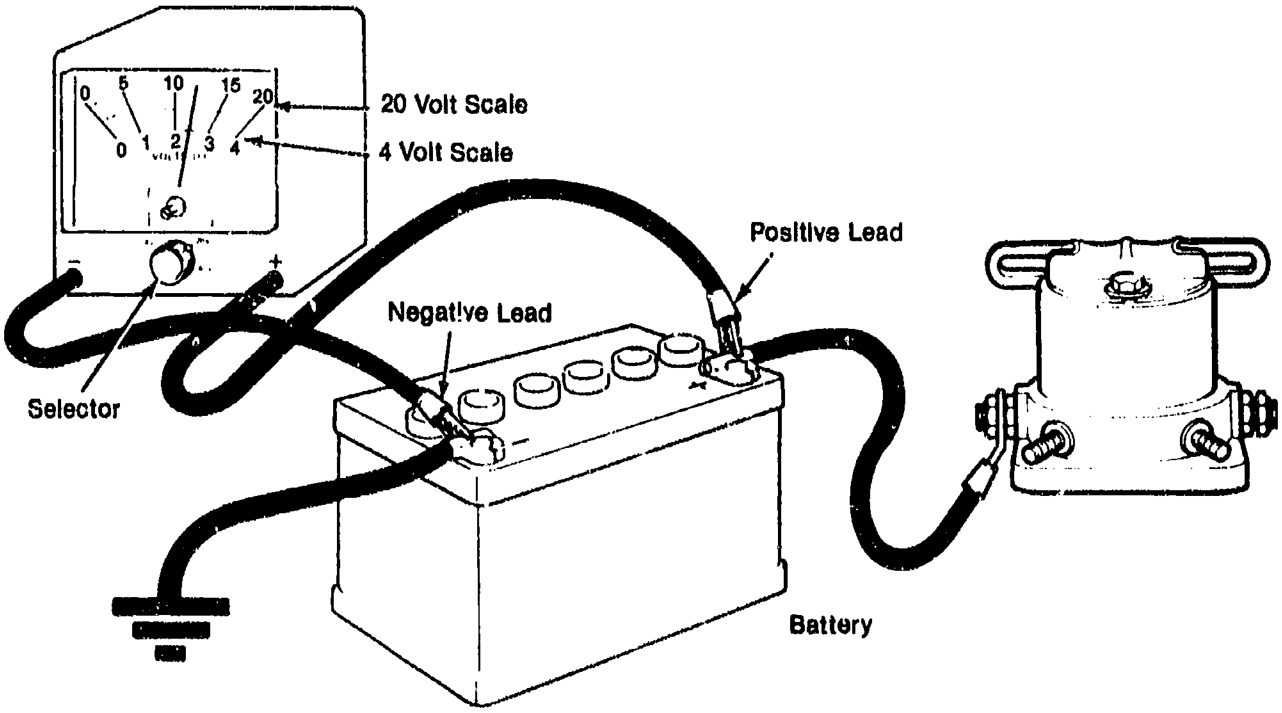
1. Battery
2. Voltmeter
3. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)

1. Connect negative lead from voltmeter to negative (–) battery terminal.
2. Connect positive lead to positive terminal (+). (Figure 1)

FIGURE 1



3. Read voltmeter scale to see if you have battery rated voltage.
4. Charge battery to its rating before performing any other electrical tests if you don't have normal battery voltage.

ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #2 — CHECK A CIRCUIT FOR AN OPEN

A. Tools and materials

1. Circuit board or vehicle
2. Voltmeter
3. Ohmmeter
4. Test light

B. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)

1. Check an open circuit using voltmeter.

   a. Connect the circuit to a battery source so current can flow through each component.

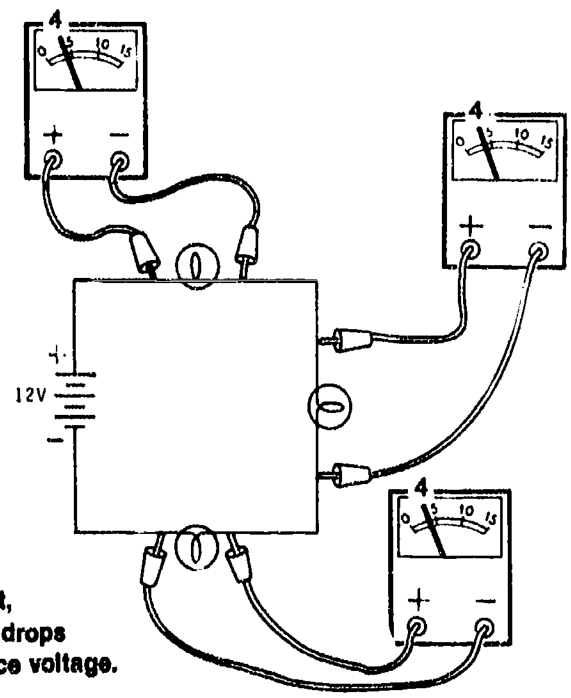
   b. Connect voltmeter leads on each side of the component.

JOB SHEET #2

c. Read voltmeter.

1) If all the components in a circuit are good, each one will drop a portion of battery voltage. (Figure 1)

FIGURE 1



In a closed circuit, each component drops a portion of source voltage.

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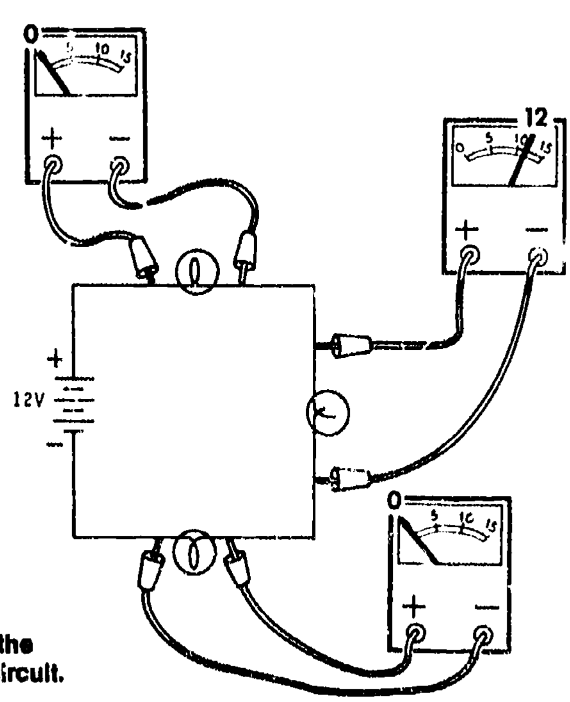
2) If one component burns out and creates an open, it will have battery voltage across its leads. The other components will have zero voltage across their leads. (Figure 2)

FIGURE 2



Source voltage is measured across the open in an open circuit.

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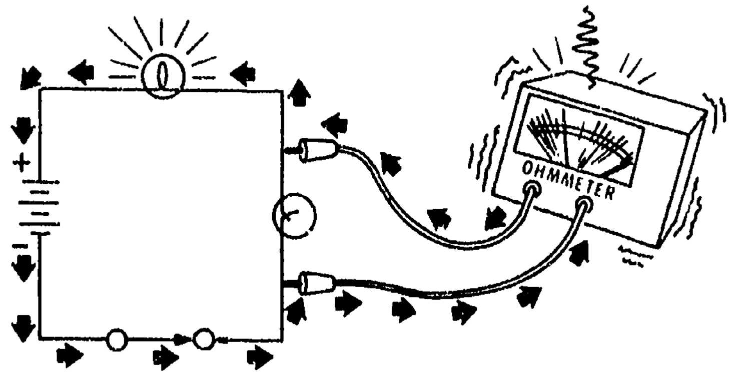
JOB SHEET #2

2. Check an open circuit using an ohmmeter.

   (CAUTION: When an ohmmeter is used to locate an open, the battery must be disconnected. See Figure 3.)

   FIGURE 3



Current flow through an ohmmeter can damage the ohmmeter.

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   a. Connect the ohmmeter to each side of the component.

   b. Read ohmmeter scale.

      (NOTE: The ohmmeter indicates an open circuit with a reading of infinite resistance.)

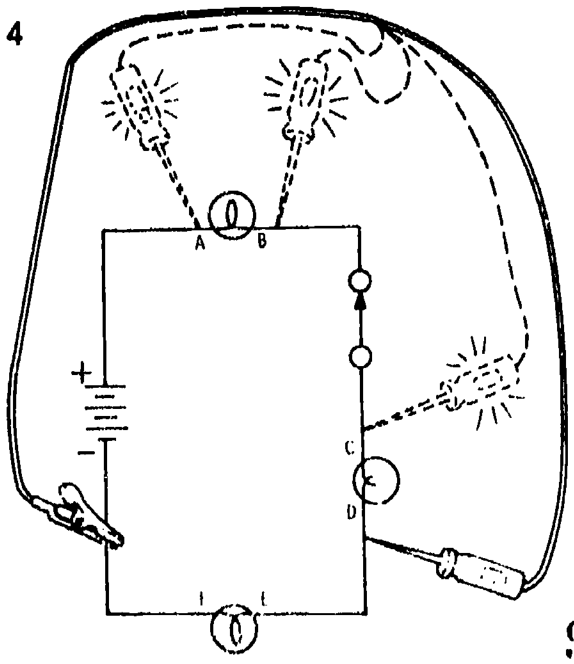
3. Check an open circuit using a test lamp.

   a. Connect the clip wire to one terminal of the battery. (Figure 4)

   b. Touch the probe at various points beginning at the other battery terminal.

      (NOTE: Each time the probe touches the circuit between the terminal and the open, its lamp will light. When it goes past the open, the test lamp will no longer light. See Figure 4.)

   FIGURE 4



Locating an open with a test lamp.

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ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #3 — INSTALL A SOLDERED TERMINAL

A. Tools and equipment

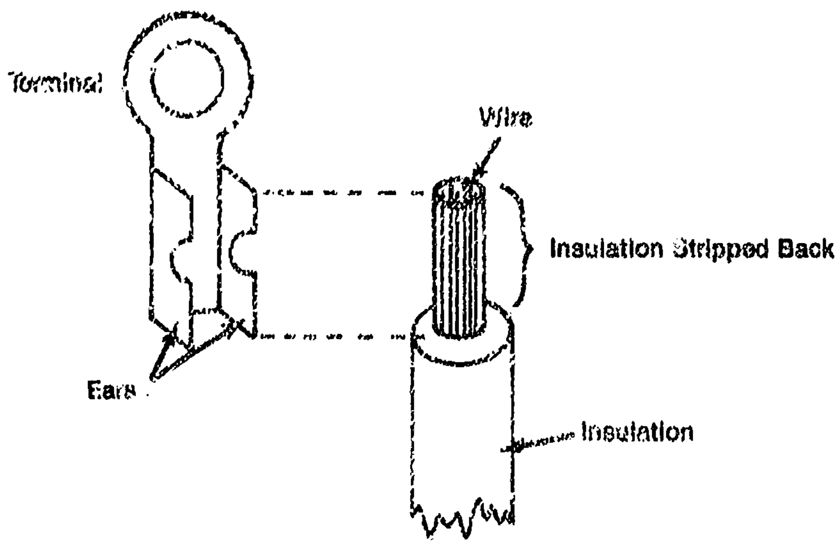
1. Soldering gun or iron
2. Resin core solder
3. Medium sandpaper
4. Terminal
5. Electrical wire
6. Electrical tape
7. Safety glasses

B. Procedure

1. Strip end of insulation back from wire to permit installation of terminal. (Figure 1)

   (NOTE: Always use the same size wire as originally used by the manufacturer.)

   FIGURE 1

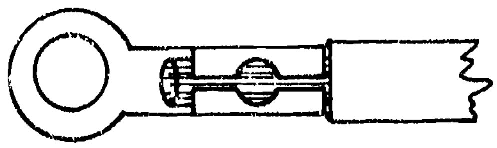


2. Clean terminal with sandpaper.

JOB SHEET #3

3. Place wire in terminal and bend ears of terminal around wire. (Figure 2)

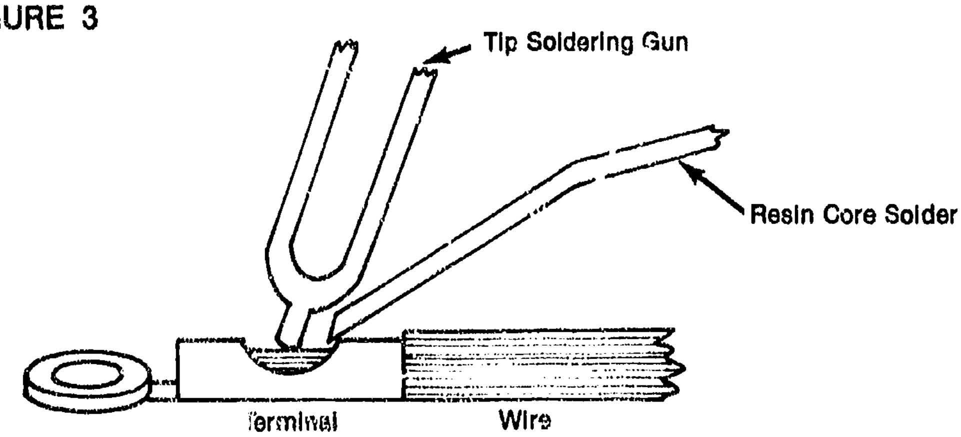
FIGURE 2



4. Solder terminal to wire. (Figure 3)

(CAUTION: Use only resin core solder on electrical connections.)

FIGURE 3

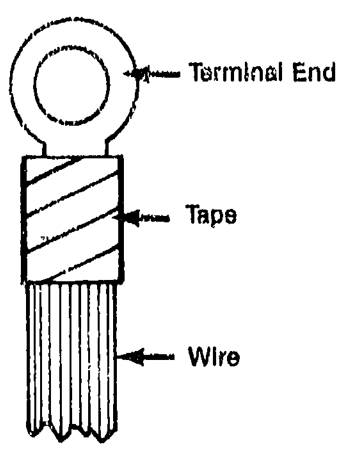


(NOTE: The purpose of the soldering iron is not to melt the solder itself but to heat the parts being soldered to a temperature high enough to melt solder when it is touched to the work.)

5. Tape connection. (Figure 4)

(NOTE: It is only necessary to tape the connection if solder crimp area will contact or ground against a metal area.)

FIGURE 4



ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #4 — INSTALL A SOLDERLESS TERMINAL

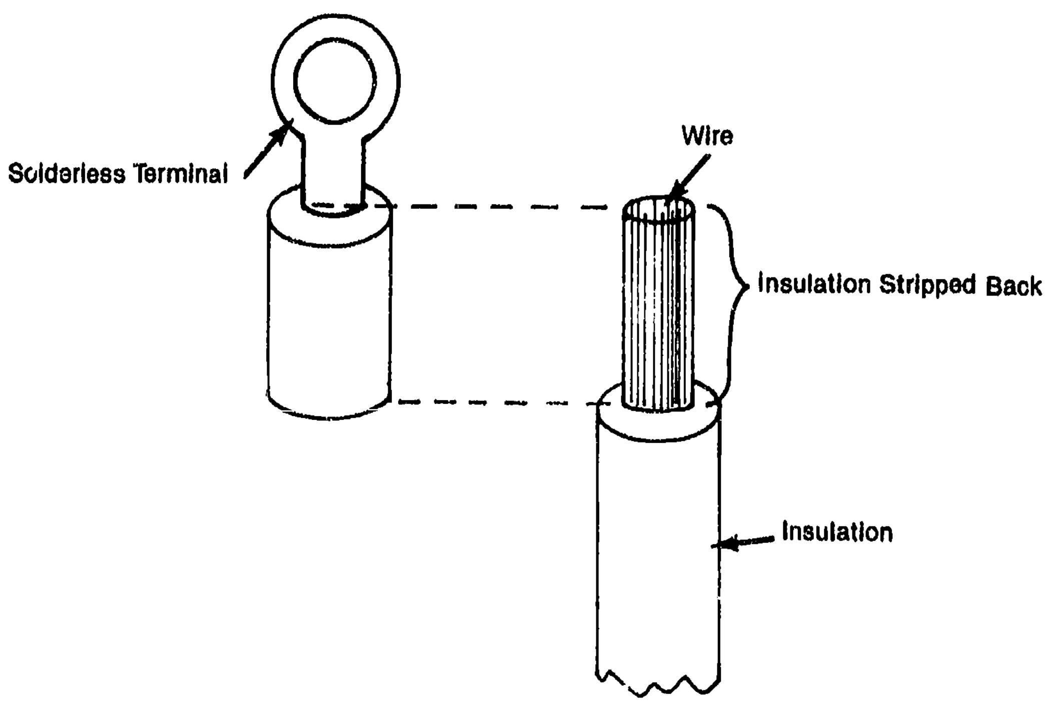
A. Tools and equipment

1. Crimping pliers
2. Terminal

B. Procedure

1. Strip insulation from wire to fit terminal. (Figure 1)

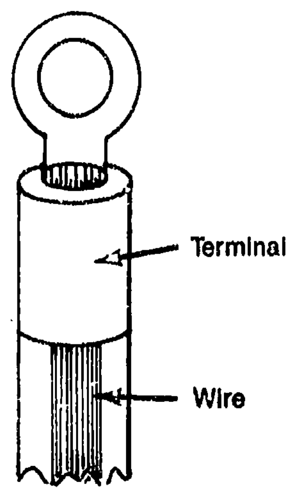
FIGURE 1



JOB SHEET #4

2. Insert wire into terminal. (Figure 2)

FIGURE 2



(NOTE: Always use the terminal that fits the wire properly.)

3. Crimp the terminal to the wire.

(NOTE: Use the correct crimper opening when crimping the terminal to the wire.)

4. Connect terminal and wire to power source.

(NOTE: Always use the proper size wire when making a repair.)

ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #5 — SPLICE A WIRE (SOLDER METHOD)

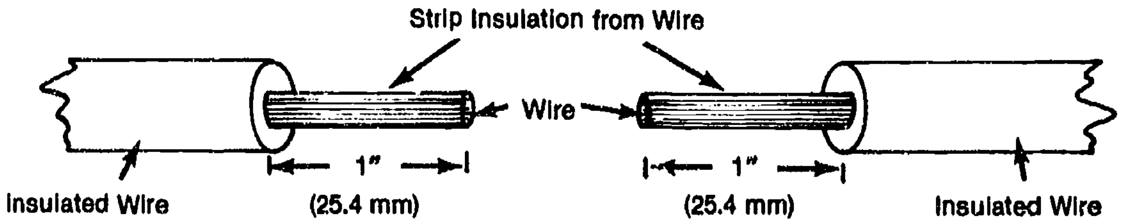
A. Tools and equipment

1. Soldering gun or iron
2. Electrical wire
3. Resin core solder
4. Electrical tape
5. Safety glasses

B. Procedure

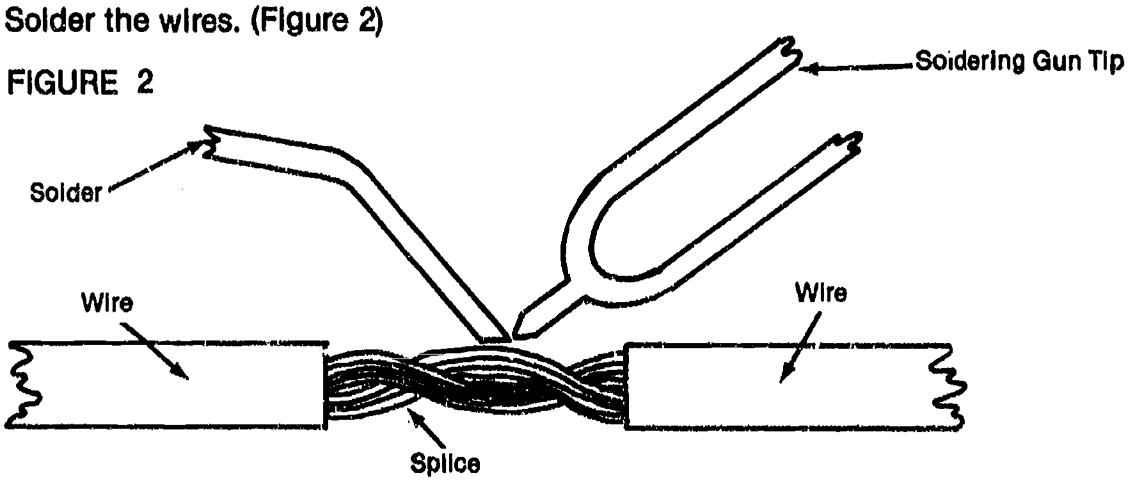
1. Strip back insulation one inch (25.4 mm) from ends of wire. (Figure 1)

FIGURE 1



2. Intertwine the wire ends together.
3. Twist the strands together.
4. Solder the wires. (Figure 2)

FIGURE 2



(NOTE: Allow the soldering iron to heat the wire first, then apply solder as shown. Only flow enough solder on splice to hold wire securely. Do not waste solder or build up joint. If splice has too much solder, the splice joint will break.)

5. Tape splice by wrapping neatly with electrical tape.

ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #1 — CHECK VOLTAGE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Connected voltmeter leads to the battery correctly.	______	______
3. Read voltmeter scale.	______	______
4. Checked in/put away tools and materials.	______	______
5. Cleaned the work area.	______	______
6. Used proper tools correctly.	______	______
7. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
8. Practiced safety rules throughout procedure.	______	______
9. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Evaluation of battery condition				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #2 — CHECK A CIRCUIT FOR AN OPEN

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked for an open circuit using a voltmeter.	______	______
3. Checked for an open circuit using an ohmmeter.	______	______
4. Checked for an open circuit using a test lamp.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Found the open				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #3 — INSTALL A SOLDERED TERMINAL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Stripped end of insulation back from wire.	______	______
3. Cleaned terminal.	______	______
4. Soldered terminal to wire.	______	______
5. Taped connection.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Used correct amount of solder				
	4	3	2	1
Connection soldered properly				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #4 — INSTALL A SOLDERLESS TERMINAL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Stripped insulation from wire.	______	______
3. Selected the correct terminal.	______	______
4. Crimped terminal to wire using the correct crimper opening.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Wire to terminal connection				
	4	3	2	1
Appearance of terminal end				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL CIRCUITS
UNIT II

PRACTICAL TEST
JOB SHEET #5 — SPLICE A WIRE (SOLDER METHOD)

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Stripped back insulation.	______	______
3. Intertwined the wire ends together.	______	______
4. Twisted the strands together.	______	______
5. Soldered the wires.	______	______
6. Taped splice with electrical tape.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Amount of solder used	4	3	2	1
Connection soldered properly	4	3	2	1
Appearance of splice	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL CIRCUITS
UNIT II

NAME ____________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

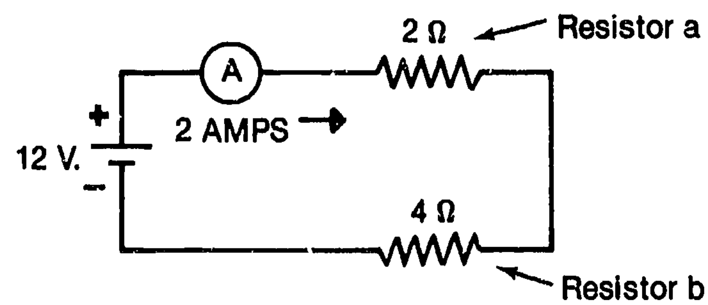
(NOTE: Terms and definitions are continued on the following page.)

_____a.	A device that opens and closes a circuit	1. Cable
_____b.	Stranded conductor usually covered with insulating material	2. Circuit
_____c.	Sealed unit containing resistors, diodes, and transistors	3. Continuity light
_____d.	Drawing that uses electrical symbols and lines to show electrical circuits	4. Crimping tool
_____e.	Wire, usually with alligator clips, that is used to provide current or ground to an electrical device	5. Double filament bulb
_____f.	A test instrument used to find current flow	6. Gauge
_____g.	A self powered light, used to check for open circuits.	7. Ground
_____h.	A multiple connection point for current or ground which can also be used as a test point	8. Integrated circuit
_____i.	Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source	9. Junction block
_____j.	Type of screw, post, pin, or socket at the end of a wire or cable	10. Jumper wire
_____k.	Refers to the grounded battery terminal or to an electrical circuit or to the north and south pole of a magnet	11. Polarity
_____l.	Any system of wires which are taped together for electrical distribution throughout the vehicle	12. Single filament bulb
_____m.	Uninsulated side of a circuit which is in a vehicle	13. Solder

TEST

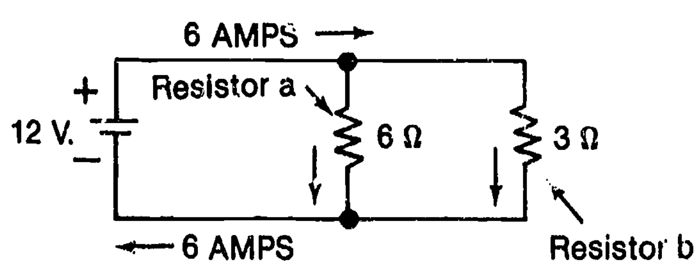
_____n.	Bulb with only one lighting element	14.	Soldering iron
_____o.	Bulb with two lighting elements	15.	Switch
_____p.	A tin lead alloy with a low melting point; used to fuse electrical connections	16.	Terminal
		17.	Test light
_____q.	Determines the diameter and the capacity of a wire or cable	18.	Wiring diagram
_____r.	A tool that delivers high temperatures; used to melt solder	19.	Wiring harness
_____s.	A tool used to crimp terminals to wires		

2. Calculate the voltage drop across each resistor in the following series circuit.



a. ______________________ b. ______________________

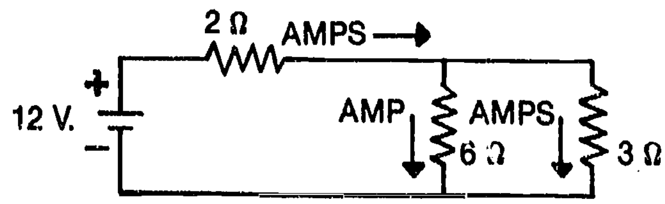
3. Calculate the current going through each resistor in the following parallel circuit.



a. ______________________ b. ______________________

TEST

4. Calculate the current going through the resistor that is in series, in the following series-parallel circuit.



Answer ______________

5. Match the basic electrical circuit failures on the right with the correct causes.

_____a.	Break in an electrical circuit which causes extremely high resistance	1.	Grounded circuit
_____b.	Unwanted connection, usually copper to copper, that allows current to bypass all or part of the circuit	2.	High resistance circuit
_____c.	Unwanted connection that bypasses all or part of the circuit from the insulated side to the grounded side of the circuit	3.	Open circuit
_____d.	Failure caused by poor or corroded connections or damaged wires which reduces current flow in the circuit	4.	Shorted circuit

6. Select true statements concerning voltage drop by placing an "X" beside each statement that is true.

_____a. Voltage drop occurs when electricity flows through a resistance.

_____b. Voltage drop can be measured directly by connecting the voltmeter across the component with the circuit turned off.

_____c. Voltage drop can be measured by connecting a voltmeter on each end of the component or wire to ground.

_____d. Voltage drop adds up when connected in series with the load.

7. Name three types of circuit protection.

a. ______________________________

b. ______________________________

c. ______________________________

TEST

8. Complete the following statements concerning selection of cable for rewiring needs by inserting the word that best completes each statement.

   a. Cable should be of proper ______________ size to handle maximum required electrical loads.

   b. Cable should feature ______________ and covering materials which provide the longest cable life possible.

9. Select from the following list characteristics of a wiring diagram by placing an "X" beside each characteristic.

   ______a. Wiring diagrams are needed only for beginning mechanics.

   ______b. Lines represent wires.

   ______c. Wires have identification numbers.

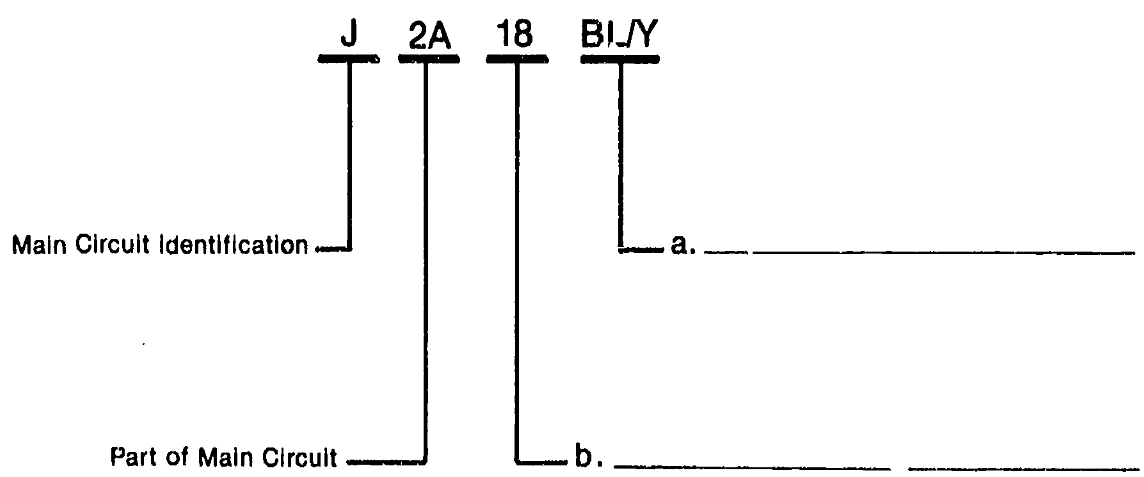
   ______d. Troubleshooting suggestions are included on the diagram.

   ______e. Wires are color coded.

   ______f. Components are represented by symbols.

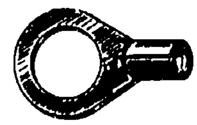
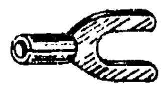
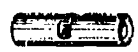
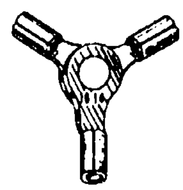
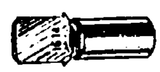
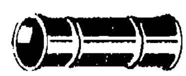
   ______g. Symbols indicate locations of circuits or components in the vehicle.

10. Label the parts of the following circuit identification code by filling in the blanks.



TEST

11. Match the types of connectors on the right with their correct names.

______a.	Three way connector	1.	
______b.	Roll type	2.	
______c.	Female slide connector	3.	
______d.	Female snap-on	4.	
______e.	Insulated butt connector	5.	
______f.	Slotted-flange bay type	6.	
______g.	Lug type	7.	
______h.	Ring type	8.	
______i.	Male slide connector	9.	
______j.	Male plug connector	10.	
______k.	Slotted hook type	11.	
______l.	Female plug connector	12.	

TEST

12. Arrange in order the steps to follow in troubleshooting electrical systems by placing the correct sequence number in the proper blank.

_____a. Inspect the system.

_____b. Reach a conclusion.

_____c. Know the system.

_____d. Operate the machine.

_____e. Ask the operator.

_____f. Test your conclusion.

_____g. List the possible cause.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Read a wiring diagram. (Assignment Sheet #1)

14. Demonstrate the ability to:

    a. Check voltage. (Job Sheet #1)

    b. Check a circuit for an open. (Job Sheet #2)

    c. Install a soldered terminal. (Job Sheet #3)

    d. Install a solderless terminal. (Job Sheet #4)

    e. Splice a wire (solder method). (Job Sheet #5)

ELECTRICAL CIRCUITS
UNIT II

ANSWERS TO TEST

1.
a.	15	h.	9	o.	5
b.	1	i.	2	p.	13
c.	8	j.	16	q.	6
d.	18	k.	11	r.	14
e.	10	l.	19	s.	4
f.	17	m.	7		
g.	3	n.	12		

2. a. 4 volts
   b. 8 volts

3. a. 2 amps
   b. 4 amps

4. 3 amps

5. a. 3
   b. 4
   c. 1
   d. 2

6. a, c, d

7. a. Fuses
   b. Circuit breaker
   c. Fusible links

8. a. Gauge
   b. Insulating

9. b, c, e, f, g

10. a. Color of wire
    b. Gauge of wire

11.
a.	9	e.	7	i.	10
b.	2	f.	6	j.	11
c.	5	g.	4	k.	8
d.	3	h.	1	l.	12

12.
a.	3	e.	2
b.	6	f.	7
c.	1	g.	5
d.	4		

ANSWERS TO TEST

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL INDICATOR CIRCUITS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to test gauges, sending units, and indicator light circuits. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical circuits with their correct definitions.
2. Match electrical indicator circuits with their correct functions.
3. Name two electric gauge operation designs.
4. Arrange in order the steps in the operation of magnetic gauges.
5. Name three types of sending units.
6. Distinguish between oil pressure and temperature indicator light circuits.
7. Name two types of charging indicator circuits.
8. Demonstrate the ability to:
    a. Test gauges and sending units (tank unit method). (Job Sheet #1)
    b. Test gauges and sending units (grounded wire method). (Job Sheet #2)
    c. Test oil pressure indicator light. (Job Sheet #3)
    d. Test temperature indicator light. (Job Sheet #4)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparency from the transparency master included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparency to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Give students a wiring diagram and have them trace the indicator circuits.

2. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Blanchard and Ritchen. *Auto Engines and Electrical Systems.* 5th ed. New York, NY: Motor, 1970.

B. *Fundamentals of Service: Electrical Systems.* 4th ed. Moline, IL: Deere & Company, 1979.

C. Graf, Rudolf F. and George V. Whalen. *Automotive Electronics.* Indianapolis, IN: Howard W. Sams and Co., 1970.

D. Schulz, Erich J. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Co., 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Text

Automotive Electronics and Electrical Equipment, 9th ed.
Order #014831-7
Gregg/McGraw-Hill
P.O. Box 996
Norcross, GA 30091
(404) 449-1837

B. Filmstrip

Basic Troubleshooting and Repair of Automotive Electrical Components
Order #B-461
3 cassettes, 3 filmstrips, study guide
Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92628-0798

ELECTRICAL INDICATOR CIRCUITS
UNIT III

INFORMATION SHEET

I. **Terms and definitions**

A. Gauge — Instrument with a graduated scale

B. Indicator light — A light in the dash that indicates a problem in the system

C. Pyrometer — A sensitive voltmeter that measures exhaust temperature

D. Sending unit (sender) — Variable resistor that controls the current flowing through the gauge which affects needle movement

II. **Electrical indicator circuits**

(NOTE: Gauges and indicating lights are used in various combinations.)

A. Fuel indicator circuit — Gauge and tank unit to indicate the quantity of fuel in the tank

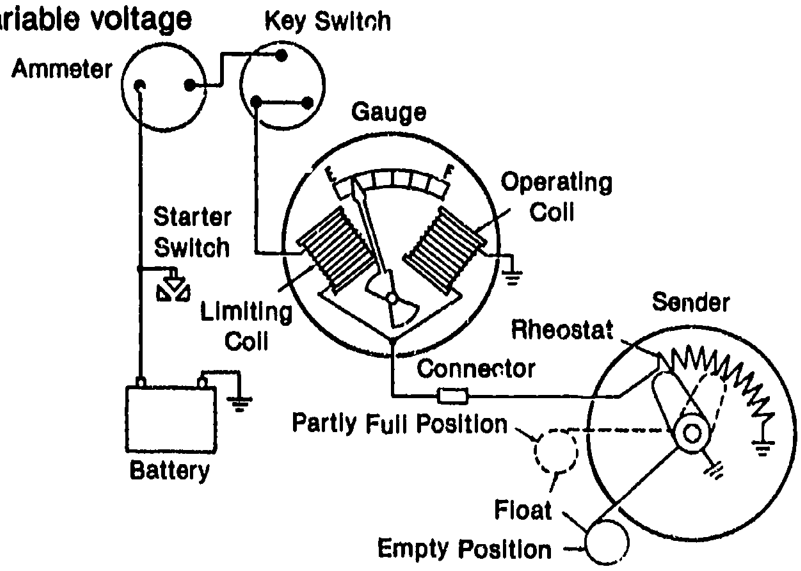
B. Temperature indicator circuit — Dash panel and engine unit to indicate the temperature of the engine coolant or engine oil

C. Oil pressure indicator circuit — Dash panel and engine unit to indicate engine oil pressure

D. Charging indicator circuit — Dash panel unit to indicate alternator charging rate

III. **Electric gauge operation design**

A. Variable voltage



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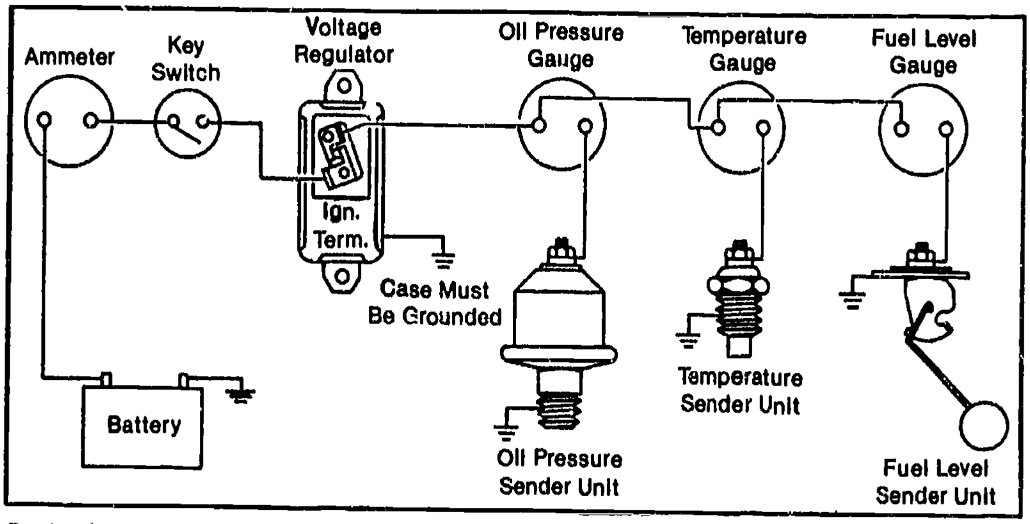
(NOTE: Current is directed from the ammeter to the key switch, to the gauge, to the sender, and then to ground.)

INFORMATION SHEET

B. Constant voltage

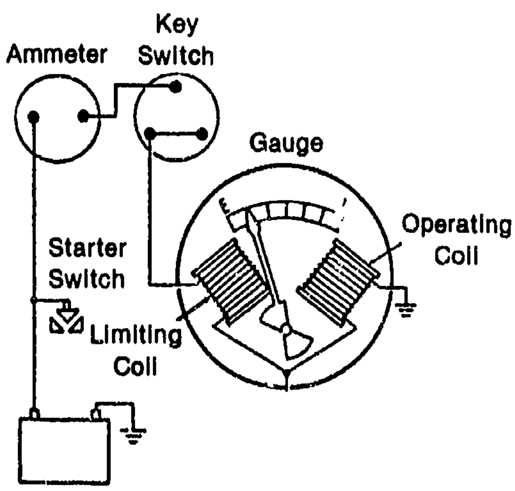


(NOTE: Current flow is the same as in the variable voltage design. The voltage regulator is to regulate the variable (input) voltage from the ammeter, to produce a constant 5.0 volts output to the gauges.)

IV. Operation of the fuel, temperature, and oil pressure magnetic gauges

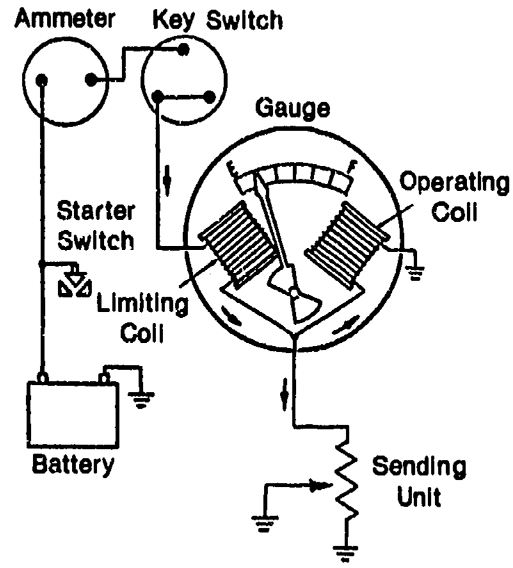
(NOTE: The following procedures apply to AC, Auto-Lite and Stewart-Warner variable voltage systems.)

A. Current from the battery passes through the limiting coil to the common connection between the two coils.



INFORMATION SHEET

B. Current can take two paths, one through the operating coil of the gauge and the other through the wire to the sending unit.



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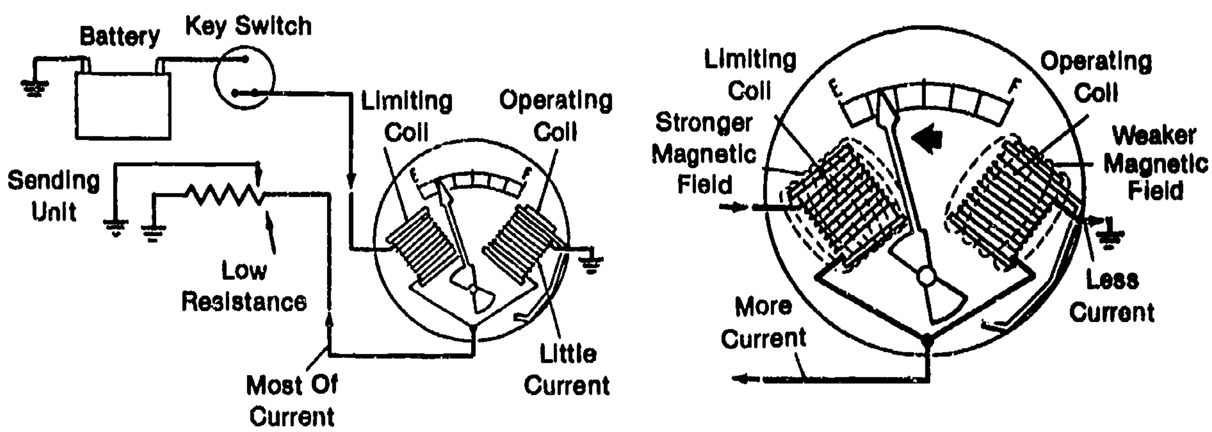
C. With low resistance in the sending unit, only a small amount of current flows through the operating coil.

(NOTE: With more current going through the limiting coil, it becomes magnetically stronger and the needle is pulled to the left.)



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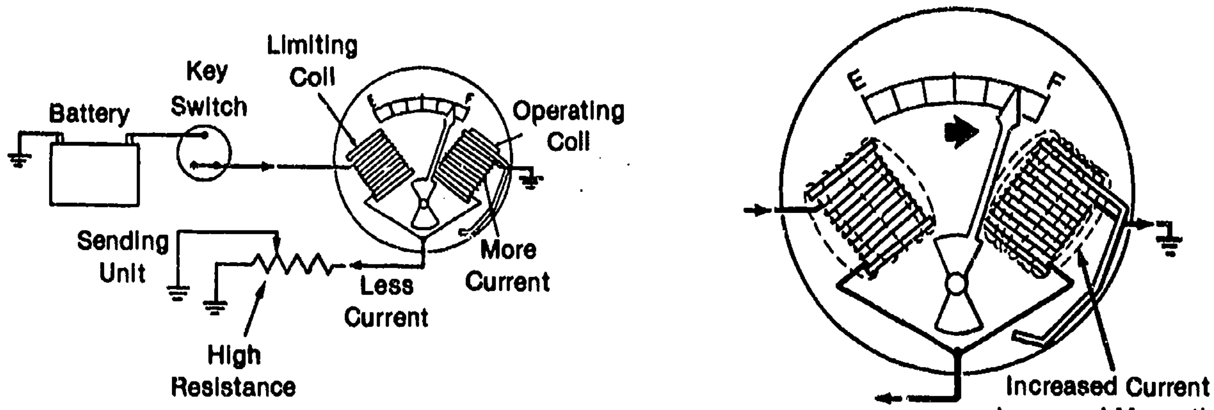
INFORMATION SHEET

D. With high resistance in the sending unit, more current will pass through the operating coil.

(NOTE: As the magnetic strength of the operating coil increases, the needle is pulled to the right.)



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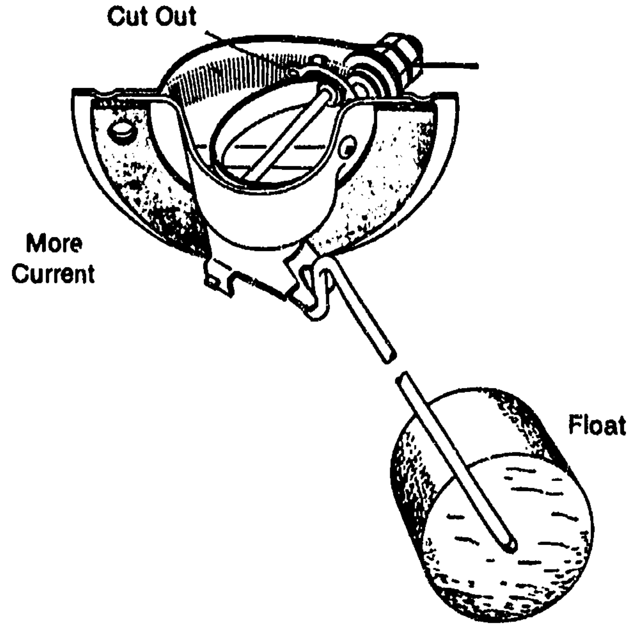
V. **Sending units**

A. Fuel

1. When the tank is empty, or the fuel supply is low, the sliding brush has moved to eliminate all resistance in the sending unit.



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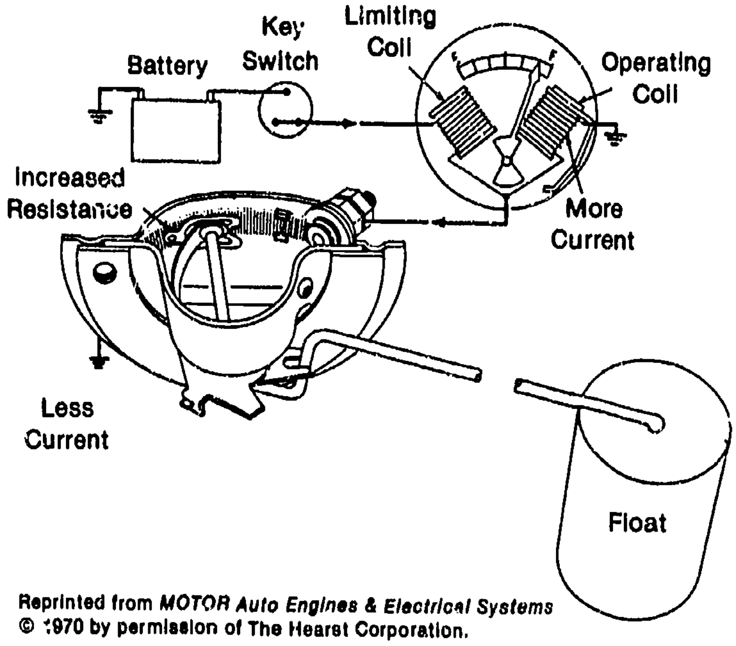
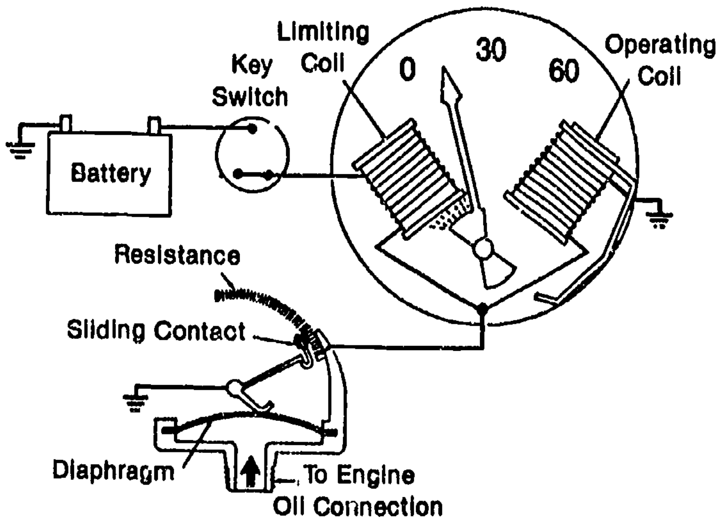
INFORMATION SHEET

2. When the tank is full, a higher fuel level moves the sliding brush along the rheostat, increasing the resistance.



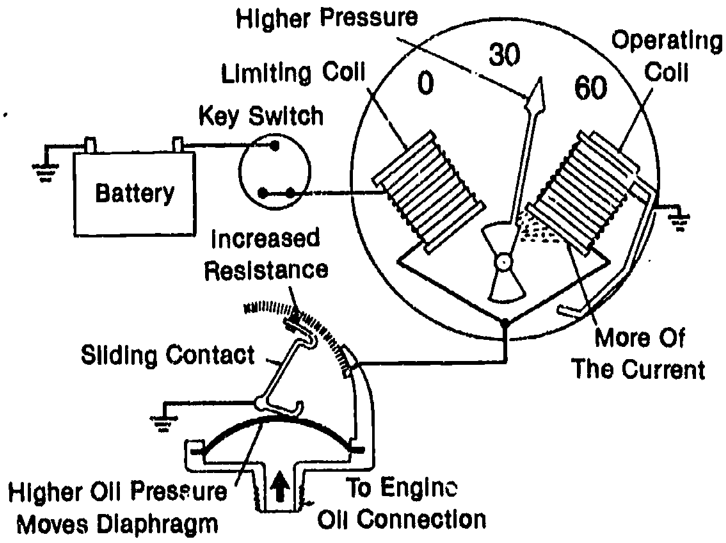
B. Oil pressure (Transparency 1)

1. When the oil pressure is low, the diaphragm moves the sliding contacts a small distance causing a small amount of resistance.



INFORMATION SHEET

2. When the oil pressure is higher, the diaphragm is flexed more, causing higher resistance.



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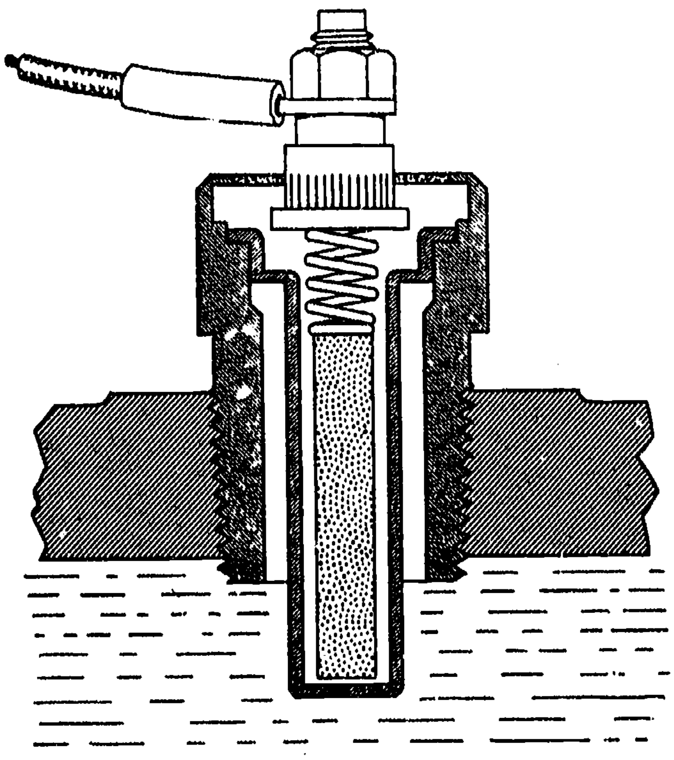
C. Temperature

1. The element in the sending unit has a high resistance value when cold and a low resistance value when hot.



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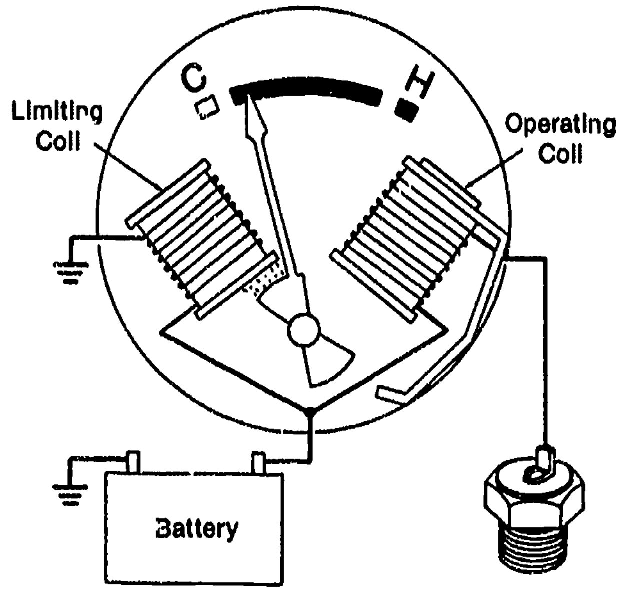
INFORMATION SHEET

2. As the sending unit heats, its lowered resistance allows more current to flow through the operating coil thus pulling the needle to the high or "HOT" side of the scale.



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VI. **Operation of the oil pressure and temperature indicator light circuits**

A. Oil pressure (Transparency 1)

1. The light is wired in series with the ignition switch and the sending unit.

   (NOTE: The sending unit contains a diaphragm and a set of contacts.)

2. When the ignition switch is turned on, current goes through the light and through the closed contacts.

3. When the engine is started, build-up of oil pressure compresses the diaphragm, opening the contacts, thereby breaking the circuit and putting out the light.

B. Temperature

1. A bimetallic sensing switch is connected in series with an incandescent lamp, mounted on the instrument panel and excited by the battery.

2. Under normal conditions the lamp remains off.

   (NOTE: As a test circuit, when the ignition is in "start" position, the red bulb will be lit if it is functioning properly.)

3. If the water temperature should reach a point where the engine approaches an overheated condition, the red light will be turned on by the sending unit (temperature switch).

INFORMATION SHEET

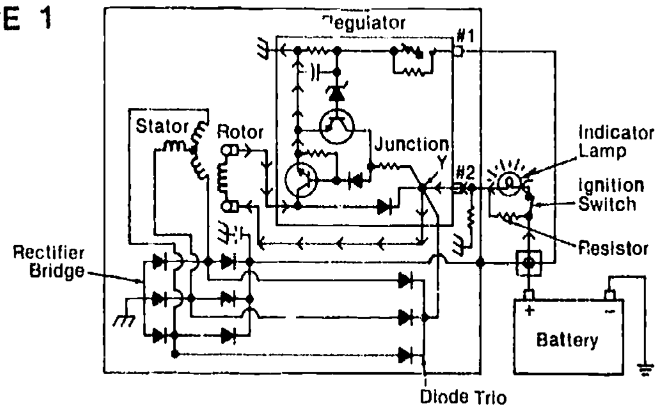
VII. Charging indicator circuits

A. Indicator light

1. Terminal #1 of the voltage regulator is connected with the parallel indicator lamp and resistor to the key switch.

2. With the key switch on, current flows from the battery through the switch, the resistor, and light indicator to #1 terminal and onto junction Y, causing the indicator lamp to burn. (Figure 1)

FIGURE 1

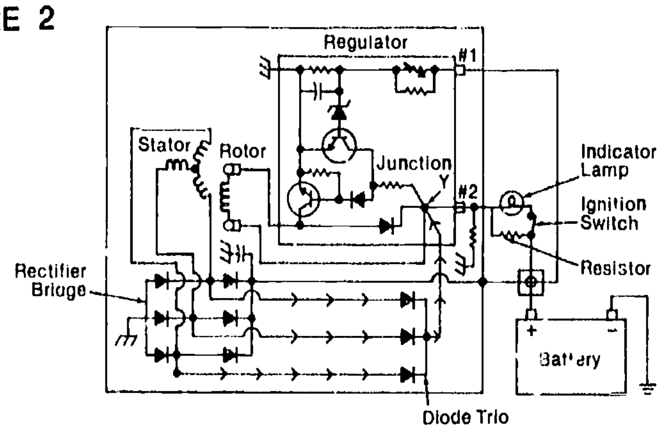


10 SI Alternator

3. When the alternator starts charging, current flows through the diode trio to junction Y.

4. When the voltage at junction Y equals battery voltage, the indicator lamp will go out. (Figure 2)

FIGURE 2



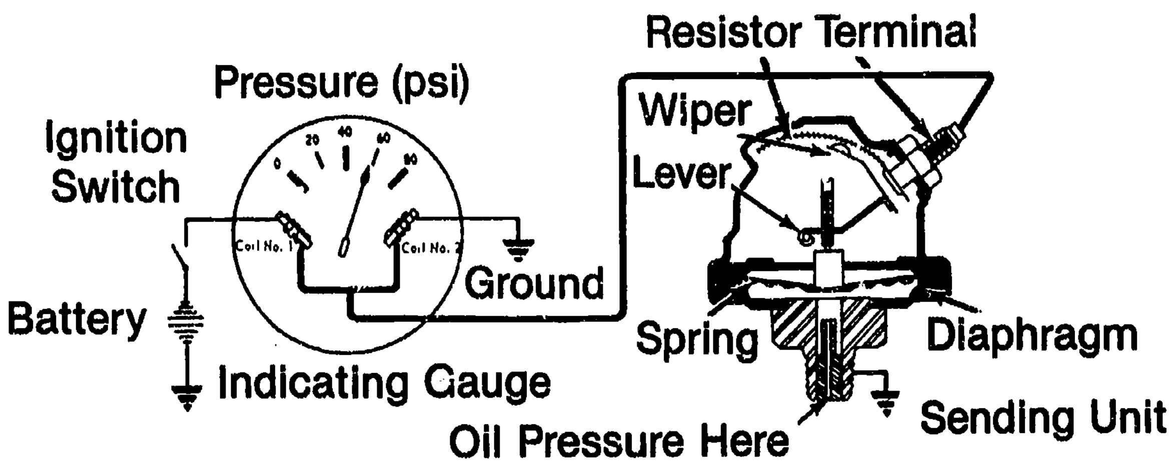
10 SI Alternator

B. Ammeter

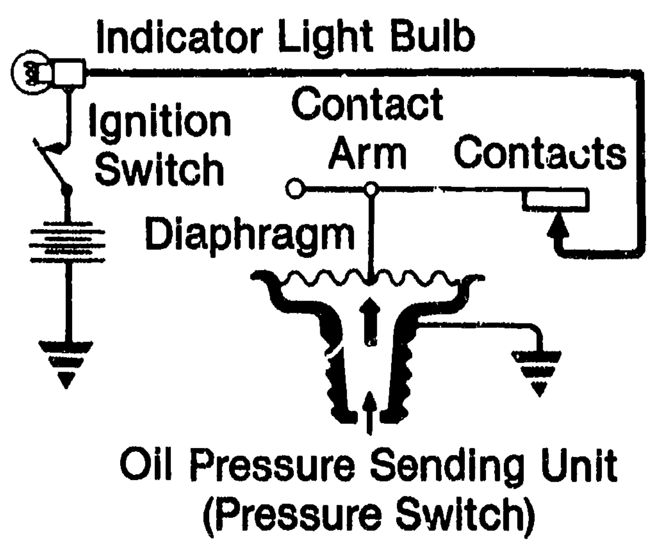
1. When current is flowing from the charging system into the battery, the pointer will be in the charge direction.

2. When the battery takes over the electrical system's load, current flows in the opposite direction, and the pointer is drawn into the discharge direction.

Electrical Oil Pressure Indicating Systems



Electromagnetic Coil System for Indicating Oil Pressure



Pressure Switch System for Indicating Oil Pressure

ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #1 — TEST GAUGES AND SENDING UNITS (TANK UNIT METHOD)

A. Tools and materials

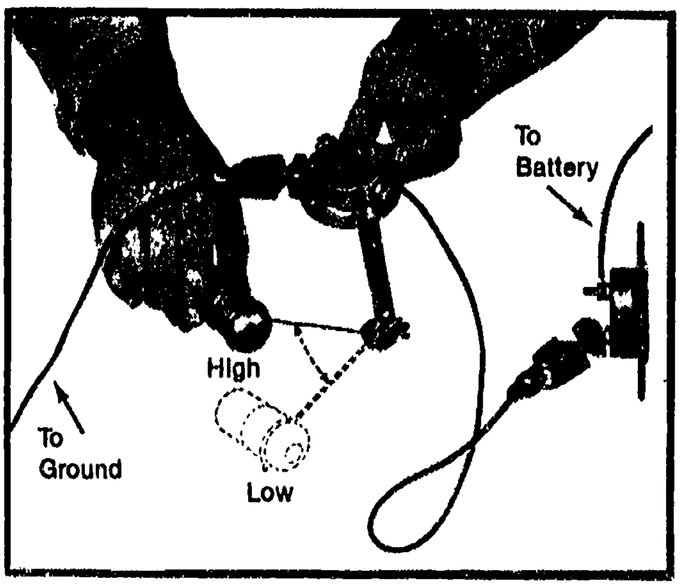
1. Vehicle
2. Basic hand tool set
3. Test light or voltmeter
4. Fuel sending unit
5. Appropriate service manual

B. Procedure

(NOTE: The following procedure is in lieu of using a commercial gauge tester.)

1. Use a spare fuel gauge tank unit known to be correct.
2. Disconnect the wire at the gauge which leads to the sending unit. This will test whether the gauge (fuel, oil, or temperature) is functioning.
3. Attach a wire lead from the gauge terminal to the terminal of the spare sending unit. (Figure 1)

FIGURE 1



JOB SHEET #1

4. Ground the spare sending unit to an unpainted portion of the dash panel and move the float arm.

5. If the gauge operates correctly, the sending unit or wiring is defective.

6. If the gauge does not operate during this test, the gauge or the voltage going to the gauge is defective.

7. If the gauge registers full scale all the time when the key switch is on, grounded wire or sending unit is at fault.

ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #2 — TEST GAUGES AND SENDING UNITS (GROUNDED WIRE METHOD)

A. Tools and materials

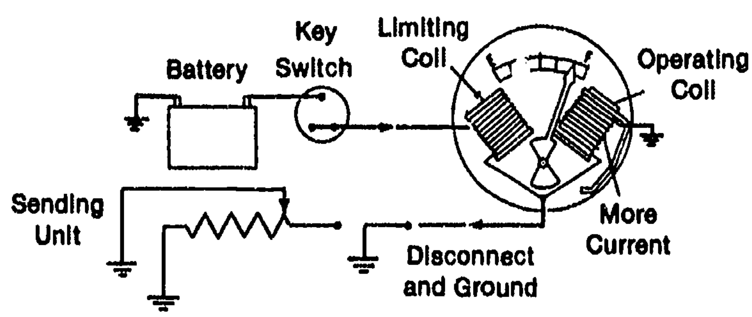
1. Vehicle
2. Basic hand tool set
3. Test light or voltmeter
4. Appropriate service manual

B. Procedure

(NOTE: The following procedure applies to variable voltage systems.)

1. Turn on key switch.
2. Remove wire connected at sending unit in question (fuel, oil, or temperature).
3. Momentarily ground wire by holding it against a clean, unpainted portion of engine, vehicle body, or frame. (Figure 1)

FIGURE 1



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4. Read the gauge pointer which should indicate a full scale reading within 30 seconds.

   (NOTE: Some oil pressure gauges will indicate zero instead of a full scale reading.)

5. If the gauge indicates a full scale reading, check

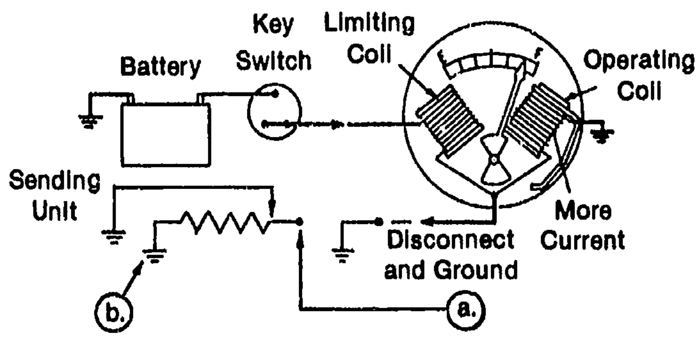
   a. For a bad connection at the sending unit, and repair it.

JOB SHEET #2

b. For defective sending unit and replace if needed. (Figure 2)

(NOTE: Both a. and b. could be at fault.)

FIGURE 2



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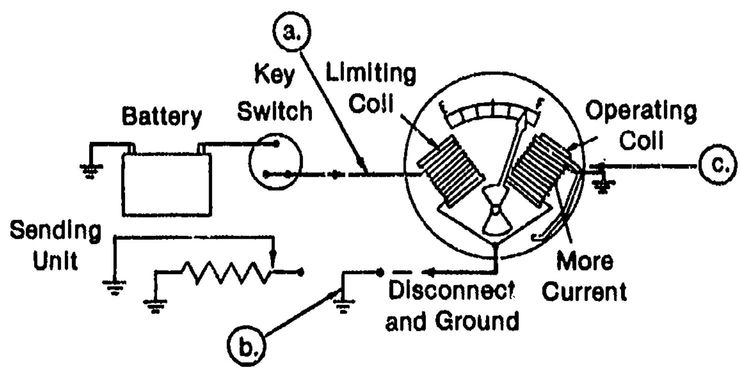
6. If during the test the gauge does not indicate a full scale reading,

   a. Repair faulty voltage at the switch terminal of the gauge.

   b. Replace or repair faulty lead wire between gauge and sending unit.

   c. Replace defective gauge. (Figure 3)

   FIGURE 3



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ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #3 — TEST OIL PRESSURE INDICATOR LIGHT

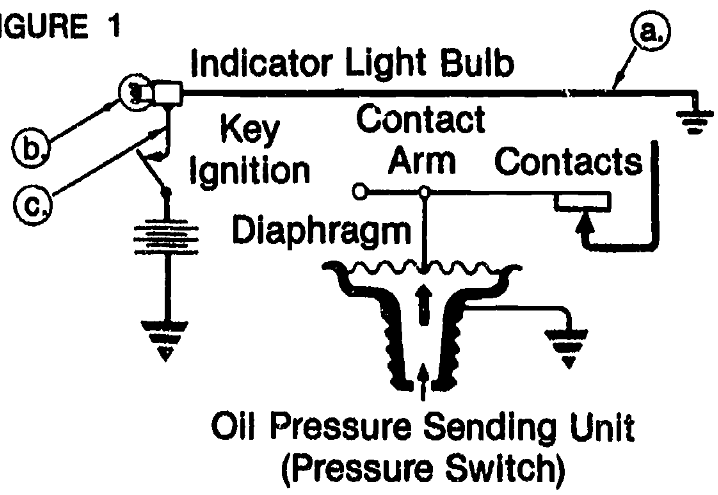
A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Test light or voltmeter
4. Appropriate service manual

B. Procedure

1. Watch for oil pressure warning light when the key is turned on.
2. If it does not light, disconnect the wire from the sending unit, and ground the wire to the frame or cylinder block. (Figure 1)

FIGURE 1



3. If the warning still does not light, check
   a. For voltage in wire coming from bulb to sending unit.
   b. Bulb.
   c. For voltage from key switch to bulb.
4. If the warning light goes on when the wire is grounded, the sending unit should be checked for looseness or poor grounding.

JOB SHEET #3

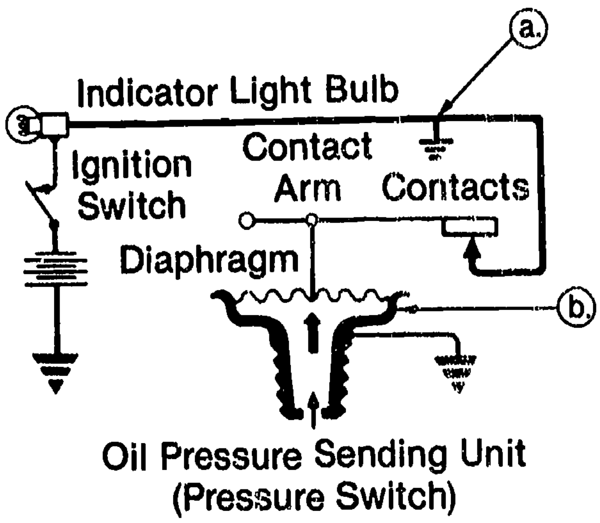
5. If the sending unit is found to be tight and properly grounded, it should be replaced.

6. If the light remains lit when engine is running, check for

   a. Grounded wire between bulb and sending unit.

   b. Bad sending unit. (Figure 2)

FIGURE 2



ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #4 — TEST TEMPERATURE INDICATOR LIGHT

A. Tools and materials

1. Vehicle
2. Test light or voltmeter
3. Basic hand tool set
4. Appropriate service manual

B. Procedure

1. Put key in "start" position to see if red light comes on. If it doesn't, ground the wire going to sending unit.
2. Turn key switch back to "start" position, and if the light is lit, replace sending unit.
3. If light stays off, check for
   a. Voltage of wire going from light to sending unit.
   b. Bad bulb.
   c. Voltage going to the switch side of the bulb.
4. Repair or replace when necessary.
5. If the light stays lit all the time, unplug wire going to sending unit.
6. If the light goes out, replace sending unit.
7. If the light still stays on, check for a ground in the wire going from the bulb to the sending unit.

ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #1 — TEST GAUGES AND SENDING UNITS (TANK UNIT METHOD)

STUDENT'S NAME ____________________ DATE __________

EVALUATOR'S NAME ____________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		YES	NO
1.	Checked out proper tools and materials.	____	____
2.	Disconnected the wire going to the sending unit.	____	____
3.	Connected the spare sending unit correctly.	____	____
4.	Operated the float on the sending unit.	____	____
5.	Determined which component was at fault.	____	____
6.	Checked in/put away tools and materials.	____	____
7.	Cleaned the work area.	____	____
8.	Used proper tools correctly.	____	____
9.	Performed steps in a timely manner (___hrs. ___min. ___sec.)	____	____
10.	Practiced safety rules throughout procedure.	____	____
11.	Provided satisfactory responses to questions asked.	____	____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Test was performed in proper sequence.	4	3	2	1
Problem was found and corrected.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #2 — TEST GAUGES AND SENDING UNITS (GROUNDED WIRE METHOD)

STUDENT'S NAME ____________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Turned on key switch.	______	______
3. Grounded wire going to sending unit.	______	______
4. Checked connection at sending unit and replaced if needed.	______	______
5. Checked voltage at the switch terminal.	______	______
6. Checked lead wire to the sending unit.	______	______
7. Replaced gauge if needed.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Test was performed in proper sequence.				
	4	3	2	1
Problem was found and corrected.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #3 — TEST OIL PRESSURE INDICATOR LIGHT

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Turned on key switch.	______	______
3. Grounded sending unit wire.	______	______
4. Checked voltage of sending unit wire.	______	______
5. Checked bulb.	______	______
6. Checked voltage in wire going from switch to wire.	______	______
7. Replaced sending unit if needed.	______	______
8. Looked for grounded wire between bulb and sending unit.	______	______
9. Replaced sending unit if needed.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Test was performed in proper sequence.				
	4	3	2	1
Problem was found and corrected.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

PRACTICAL TEST
JOB SHEET #4 — TEST TEMPERATURE INDICATOR LIGHT

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Turned the key switch to "start" position.	______	______
3. Grounded wire going to sending unit.	______	______
4. Turned key switch back to "start" position and replaced sending unit if needed.	______	______
5. Checked voltage of wire going from light to sending unit.	______	______
6. Checked bulb.	______	______
7. Checked voltage going to the switch side of the bulb.	______	______
8. Unplugged wire going to sending unit if necessary.	______	______
9. Replaced sending unit if needed.	______	______
10. Checked for a ground in the wire going from the bulb to the sending unit.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Test was performed in proper sequence.				
	4	3	2	1
Problem was found and corrected.				

EVALUATOR'S COMMENTS: ______________________________

______________ ______________________________

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

NAME ____________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Instrument with a graduated scale	1. Gauge
_____b.	A sensitive voltmeter that measures exhaust temperature	2. Indicator light
_____c.	Variable resistor that controls the current flowing through the gauge which affects needle movement	3. Pyrometer
_____d.	A light in the dash that indicates a problem in the system	4. Sending unit

2. Match the electrical indicator circuits with their correct functions.

_____a.	Gauge and tank unit to indicate the quantity of fuel in the tank	1. Charging indicator circuit
_____b.	Dash panel and engine unit to indicate the temperature of the engine coolant or engine oil	2. Fuel indicator circuit
_____c.	Dash panel and engine unit to indicate engine oil pressure	3. Oil pressure indicator circuit
_____d.	Dash panel unit to indicate alternator charging rate	4. Temperature indicator circuit

3. Name two electric gauge operation designs.

   a. ______________________________

   b. ______________________________

TEST

4. Arrange in order the steps in the operation of magnetic gauges by placing the correct sequence number in the appropriate blank.

   ______a. With low resistance in the sending unit, only a small amount of current flows through the operating coil.

   ______b. Current from the battery passes through the limiting coil to the common connection between the two coils.

   ______c. With high resistance in the sending unit, more current will pass through the operating coil.

   ______d. Current can take two paths, one through the operating coil of the gauge and the other through the wire to the sending unit.

5. Name three types of sending units.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. Distinguish between oil pressure and temperature indicator light circuits by placing an "O" next to the operation of the oil pressure and a "T" next to the operation of the temperature circuits.

   ______a. When the ignition switch is turned on, current goes through the light and through the closed contacts.

   ______b. If the water temperature should reach a point where the engine approaches an overheated condition, the red light will be turned on by the sending unit.

   ______c. When the engine is started, build-up of oil pressure compresses the diaphragm, opening the contacts, thereby breaking the circuit and putting out the light.

   ______d. Under normal conditions the lamp remains off.

   ______e. A bimetallic sensing switch is connected in series with an incandescent lamp, mounted on the instrument panel, and excited by the battery.

   ______f. The light is wired in series with the ignition switch and the sending unit.

TEST

7. Name two types of charging indicator circuits.

   a. ______________________________

   b. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

8. Demonstrate the ability to:

   a. Test gauges and sending units (tank unit method). (Job Sheet #1)

   b. Test gauges and sending units (grounded wire method). (Job Sheet #2)

   c. Test oil pressure indicator light. (Job Sheet #3)

   d. Test temperature indicator light. (Job Sheet #4)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

ANSWERS TO TEST

1. a. 1
   b. 3
   c. 4
   d. 2

2. a. 2
   b. 4
   c. 3
   d. 1

3. a. Variable voltage
   b. Constant voltage

4. a. 3
   b. 1
   c. 4
   d. 2

5. a. Fuel
   b. Oil pressure
   c. Temperature

6. a. O d. T
   b. T e. T
   c. O f. O

7. a. Ammeter
   b. Indicator light

8. Performance skills evaluated to the satisfaction of instructor

STORAGE BATTERIES
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to troubleshoot and service a battery. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to storage batteries with their correct definitions.
2. List three functions of a battery.
3. Identify two types of batteries.
4. Distinguish between the characteristics of batteries.
5. Complete statements concerning the voltage ratings of batteries.
6. Distinguish between ways of rating battery capacity.
7. Complete statements concerning rules for installing batteries.
8. Draw lines showing the installation of battery cables for different volt batteries.
9. Identify types of battery terminal constructions.
10. Select from a list safety rules to be observed during the care and maintenance of batteries.

OBJECTIVE SHEET

11. Demonstrate the ability to:

    a. Troubleshoot a battery. (Job Sheet #1)

    b. Remove, service, and replace battery. (Job Sheet #2)

    c. Measure specific gravity of a conventional battery. (Job Sheet #3)

    d. Load test a battery. (Job Sheet #4)

    e. Charge test a battery for three minutes. (Job Sheet #5)

STORAGE BATTERIES
UNIT IV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

   (NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet and handouts.

F. Discuss information sheet and handouts.

   (NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Demonstrate the use of a battery charger.

   2. Show film on heavy duty batteries.

   3. Cut an old battery in half to demonstrate battery construction.

   4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Delco Remy Service Bulletin No. 1B-115.* Anderson, IN: 1976.

B. *Delco Remy Service Bulletin No. 1B-116.* Anderson, IN: 1980.

C. *Delco Remy Service Bulletin No. 1B-188.* Anderson, IN: 1983.

REFERENCES USED IN DEVELOPING THIS UNIT

D. *Fundamentals of Service: Electrical Systems.* 4th ed. Moline, IL: Deere & Company, 1979.

E. *Sun Model VAT 28 Instruction Manual.* Chicago, IL: Sun Electric Corporation.

F. Foutes, William A. *Diesel Mechanics: Electrical Systems.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

G. Schulz, Erich J. *Diesel Mechanics,* 2nd ed. New York: McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. *Automotive Diagnosis and Tuneup* by James A. Johnson
   3rd ed., 1984.
   Gregg/McGraw-Hill
   13955 Manchester Road
   Manchester, MO 63011

2. *Delco Remy Service Manual No. 1.2*
   AC-Delco, GMC
   400 Renaissance Center
   Detroit, MI 48202

B. Filmstrips

1. *Heavy Duty Batteries*
   AC-Delco, GMC
   General Motors Building
   Detroit, MI 48202

2. *Sift Truck Battery Servicing*
   17 Minutes
   3/4" U-matic cassette
   Part No. CEVS 7525
   (NOTE: Order from your nearest Caterpillar dealer.)

STORAGE BATTERIES
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

A. Battery — Two or more connected cells which convert chemical energy into electrical energy (Transparency 1)

B. Cell — One positive plate group and one negative plate group (Transparency 1)

(NOTE: Each cell produces approximately 2 volts.)

C. Electrolyte — Solution of water and sulfuric acid

D. Hydrometer — A test instrument for determining the specific gravity of electrolyte

E. Plate group — Similar plates welded to a plate strap (Transparency 1)

F. Specific gravity — Weight of electrolyte compared to an equal volume of water at 60°F

G. Sulfated — Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

(NOTE: A sulfated condition is caused by long storage without recharging. A slow charge may or may not restore the battery.)

II. **Functions of a battery**

A. Supplies current for cranking the engine

B. Supplies current when the demand exceeds the output of the charging system

C. Stabilizes the voltage in the system during operation

III. **Types of batteries**

A. Conventional (Transparency 1)

B. Maintenance free (Transparency 2)

INFORMATION SHEET

IV. **Characteristics of batteries**

A. Conventional

1. Vent caps are used for each cell.

2. Electrolyte level has to be checked and water added to each cell.

B. Maintenance free

1. Lifetime supply of electrolyte

2. Less gassing and corrosion

3. Longer shelf life

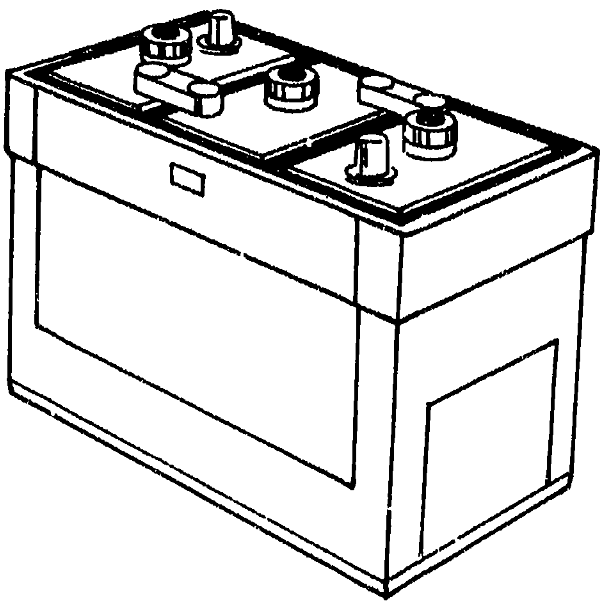
4. Some have built-in hydrometer

5. Withstand more vibration

6. Resist overcharging

V. **Voltage ratings of batteries**

A. 6-volt has 3 cells.



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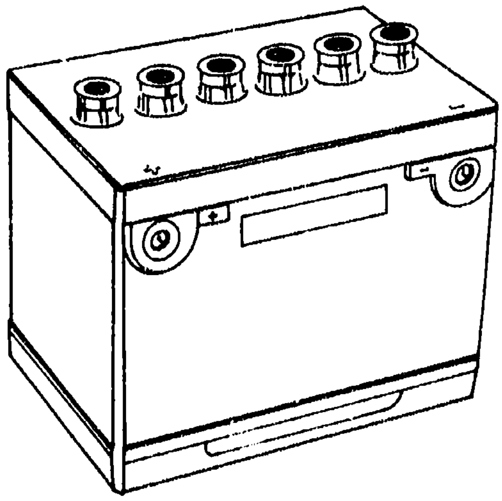
INFORMATION SHEET

B. 12-volt has 6 cells.



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(NOTE: 6 and 12 volt batteries could be either conventional or maintenance free.)

VI. Ways of rating battery capacity

A. Amp-hour rating — Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time.

Example: Battery rated at 100 amp-hour should deliver 5 amps continuously for 20 hours.

B. Cold cranking amps — Number of amps that can be taken from a fully charged battery at 0°F for 30 seconds.

Example: A battery rated at 900 cold cranking amps can produce 900 amps for 30 seconds at 0°F.

VII. Rules for installing batteries

A. Install only fully charged batteries.

B. Do not install a new battery alongside older batteries.

C. Do not install batteries of different capacities.

D. Check polarity of the vehicle before installing the batteries.

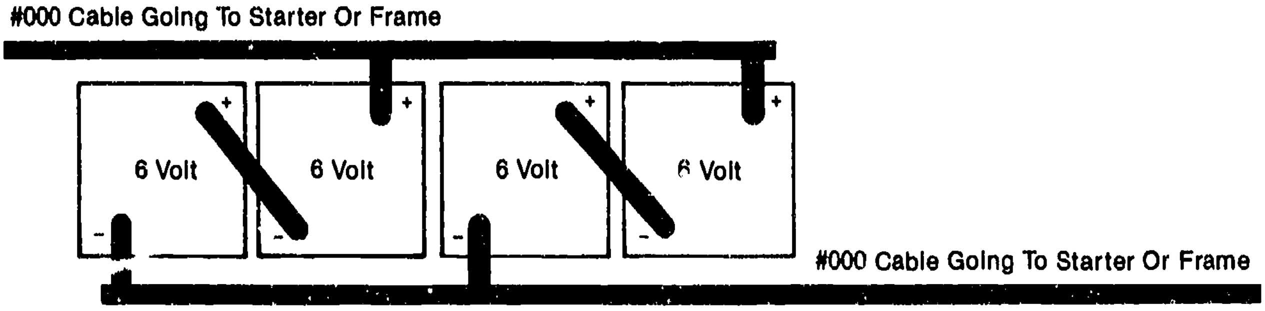
(NOTE: The ground may be to the positive or negative terminal.)

INFORMATION SHEET

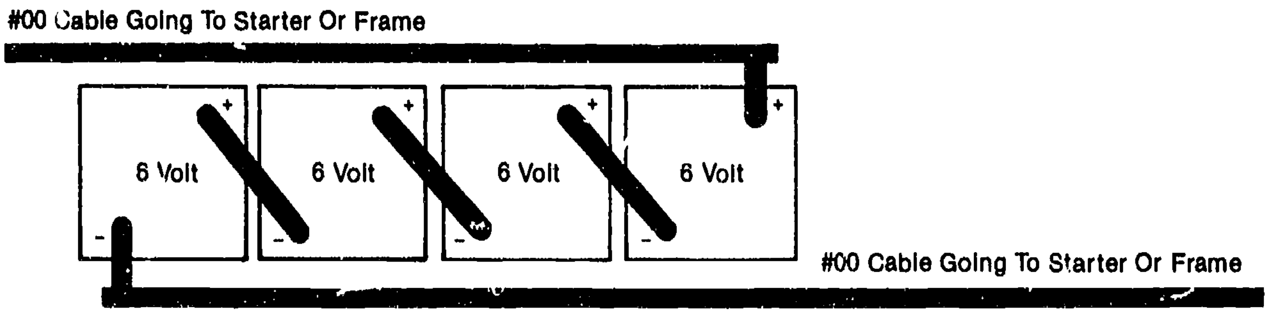
VIII. Installation of battery cables

A. 6-volt batteries

1. 12-volt system

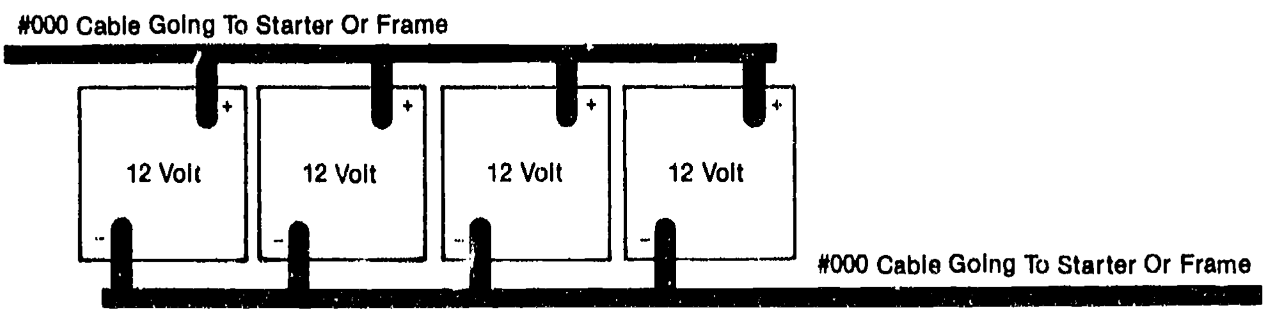


2. 24-volt system



B. 12-volt batteries

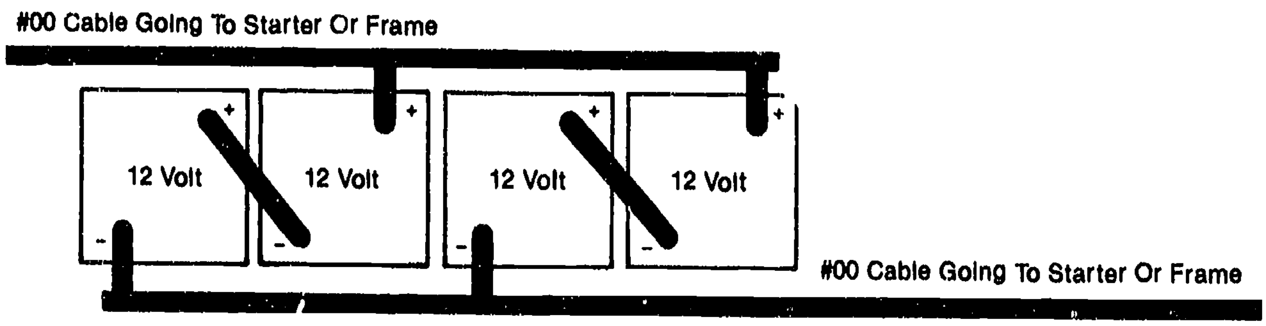
1. 12-volt system



(NOTE: When connecting positive terminals to positive terminals and negative terminals to negative terminals, amperage will increase, but voltage will stay the same.)

INFORMATION SHEET

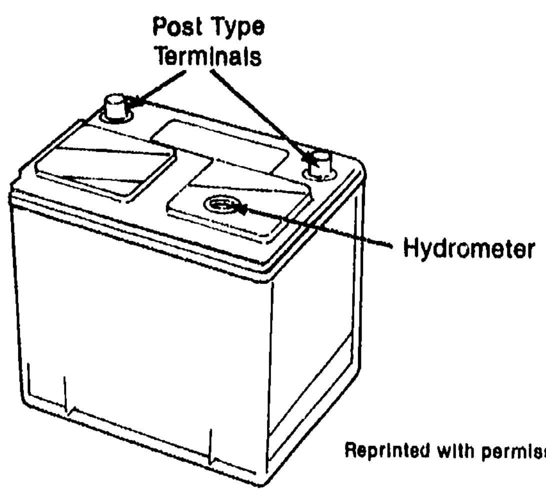
2. 24-volt system



(NOTE: When connecting positive terminals to negative terminals, amperage will stay the same, and voltage will stay the same.)

IX. **Types of battery terminal constructions**

A. Battery post terminals



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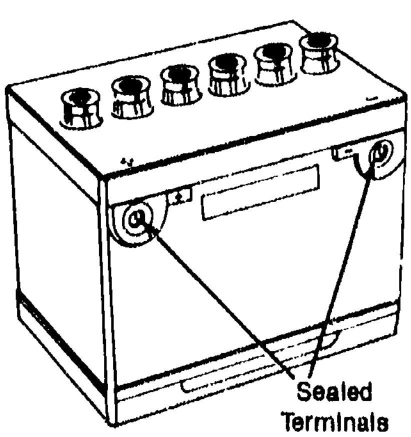
B. Bolt-type side terminals



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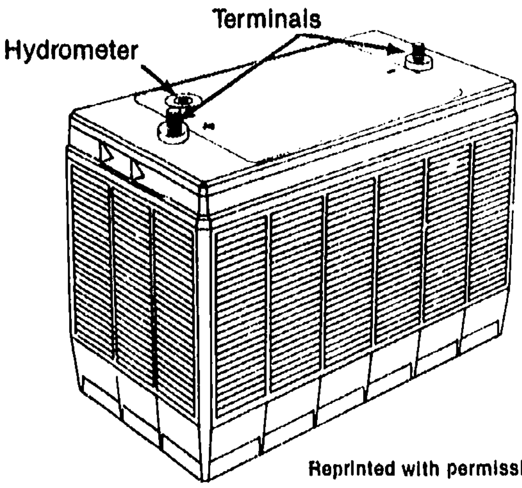
INFORMATION SHEET

C. Stainless steel stud terminals



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X. Safety rules to be observed during the care and maintenance of batteries

A. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries.

B. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces.

C. Flush immediately with water any area of skin which acid has contacted.

D. Flames or sparks can cause gases given off by battery to explode.

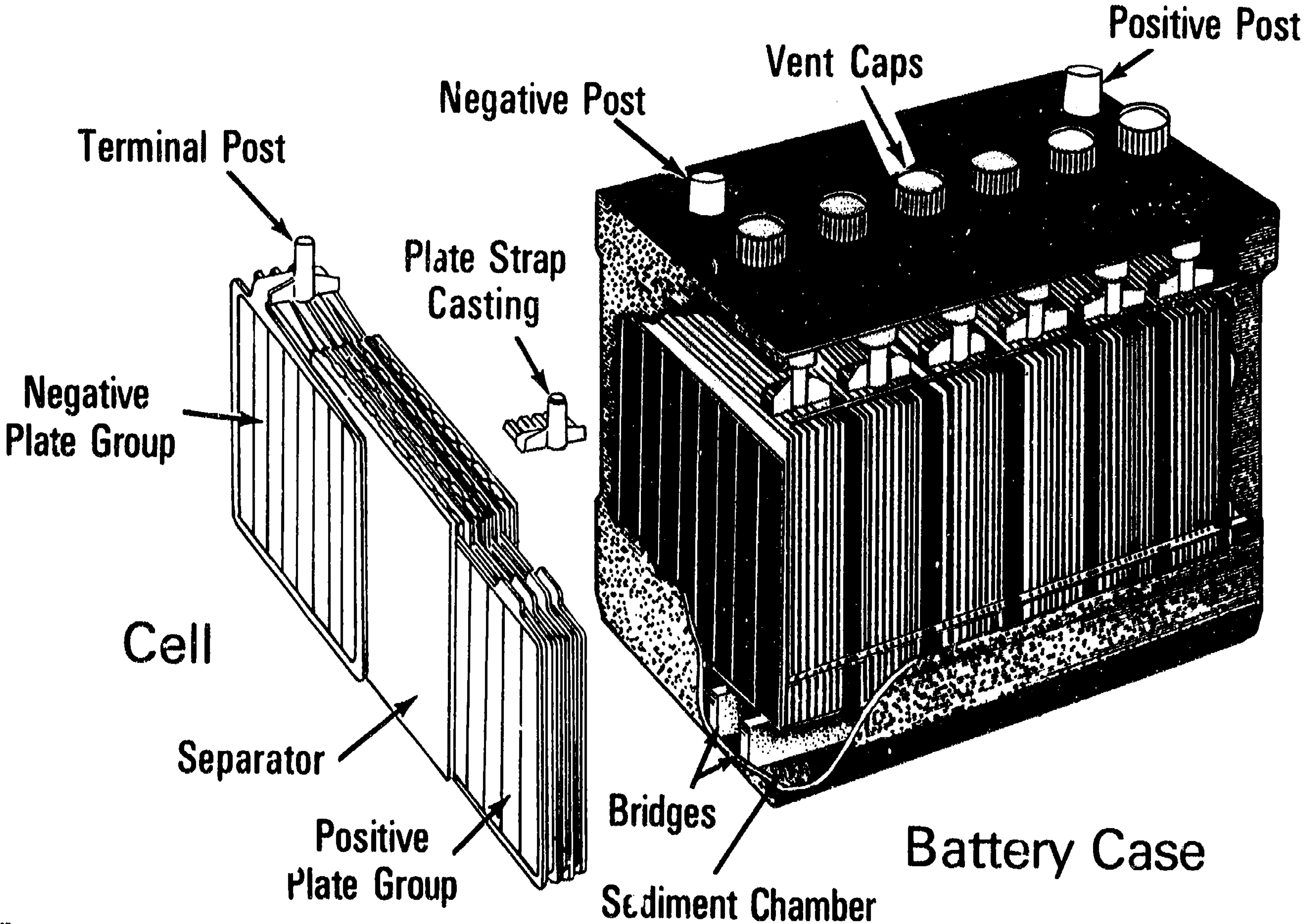
(NOTE: Gases given off are hydrogen and oxygen.)

E. Avoid shorting or grounding battery terminals during service.

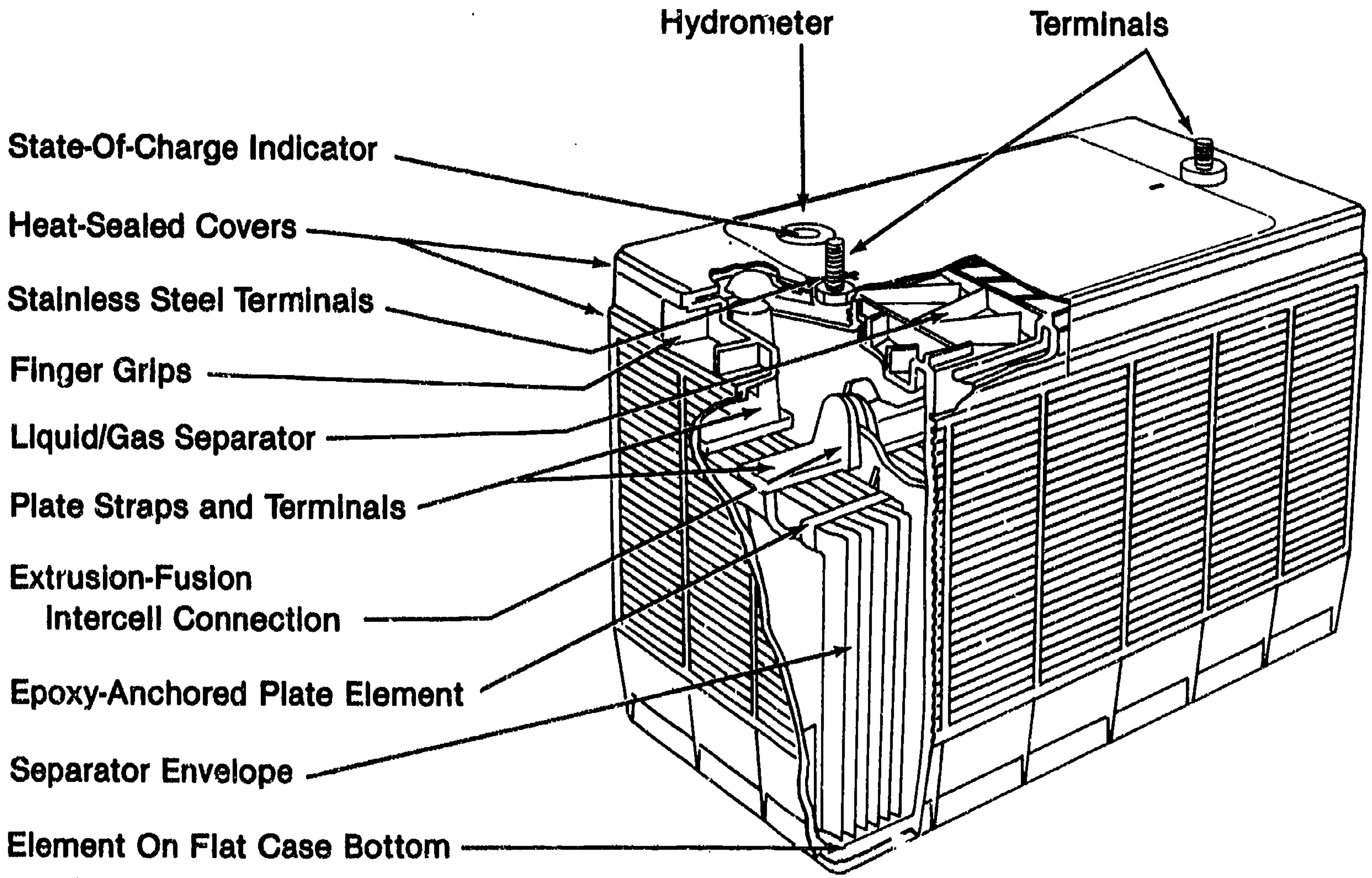
F. Avoid breathing fumes from a battery that is being charged.

G. Leave charger in the "off" position when connecting and disconnecting batteries.

Conventional Battery



Maintenance-Free Battery



STORAGE BATTERIES
UNIT IV

HANDOUT #1 — COLD CRANKING AMPS FOR MAINTENANCE-FREE BATTERIES

1. Cat. No.	2. BCI Group Size	3. Volts	4. Amps for Load Test	5. SAE — BCI Reserve Capacity (Minutes)	6. COLD CRANKING CURRENT S.A.E. SPEC. J537h @0°F. (−18°c) (in Amps.)	6. @−20°F (−29°c) (in Amps.)	7. MAXIMUM DIMENSIONS (MM/IN) 8. Length (incl. Flanges)	9. Width	10. Height (incl. Top Post)	11. APPROX. WEIGHT KG/LBS 12. Wet	13. Dry	14. ELECTROLYTE REQ'D. LITER/QTS
21-60	21	12	325	80	650	—	206/8.1	172/6.8	222/8.8	15.4/34		
21-72	21	12	320	80	650	—	206/8.1	172/6.8	222/8.8	15.1/33		
21R-60	21	12	325	80	650	—	206/8.1	172/6.8	222/8.8	15.4/34		
21R-72	21R	12	320	80	650	—	206/8.1	172/6.8	222/8.8	15.5/35		
22F-40	22F	12	160	60	330	—	229/9.0	172/6.8	210/8.3	13.0/29		
22F-50	22F	12	190	75	385	—	230/9.1	172/6.8	210/8.3	13.3/29		
22F-60	22F	12	210	75	425	—	240/9.5	172/6.8	210/8.3	14.3/31		
24-40	24	12	180	75	370	—	260/10.4	172/6.8	222/8.8	15.1/33		
24-50	24	12	230	90	475	—	260/10.2	172/6.8	222/8.8	16.5/36		
24-60	24	12	260	95	525	—	260/10.2	172/6.8	222/8.8	18.0/40		
24F-40	24F	12	180	75	370	—	270/10.6	172/6.8	222/8.8	15.2/33		
24F-50	24F	12	230	90	475	—	270/10.6	172/6.8	222/8.8	16.5/36		
24F-60	24F	12	260	95	525	—	270/10.6	172/6.8	222/8.8	17.9/39		
M24MF	24	12	200	125	400	—	260/10.2	172/6.8	194/7.6	19.9/44		
C24MF	24	12	230	90	475	—	260/10.2	172/6.8	194/7.6	16.4/36		
25-60	25	12	310	100	625	—	260/10.2	172/6.8	222/8.8	18.0/40		
25R-60	25R	12	310	100	625	—	260/10.2	172/6.8	222/8.8	18.0/40		
26-40S	26	12	180	60	370	—	206/8.1	172/6.8	202/8.0	12.3/27		
26-50S	26	12	220	70	440	—	206/8.1	172/6.8	202/8.0	12.4/27		
26-60	26	12	200	70	410	315	206/8.1	172/6.8	202/8.0	13.4/29		
26-60S	26	12	260	80	525	—	206/8.1	172/6.8	202/8.0	13.8/30		
26R-40S	26R	12	180	60	370	—	206/8.1	172/6.8	202/8.0	12.3/27		
26R-50S	26R	12	220	70	440	—	206/8.1	172/6.8	202/8.0	12.4/27		
26R-60S	26R	12	260	80	525	—	206/8.1	172/6.8	202/8.0	13.8/30		
27-50	27	12	220	90	440	—	305/12.0	172/6.8	222/8.8	18.2/40		
27-60	27	12	290	110	580	—	305/12.0	172/6.8	222/8.8	19.6/43		
27F-50	27F	12	220	90	440	—	315/12.4	172.6.8	222/8.8	18.2/40		
27F-60	27F	12	290	110	580	—	315/12.4	172.6.8	222/8.8	19.6/43		
27FMF	27	12	270	160	550	-	305/12.0	172/6.8	222/8.8	23.6/52		
27MF	27	12	270	160	550	—	321/12.8	172/6.8	222/8.8	23.5/62		
M27MF	27	12	270	160	550	—	320/12.5	172/6.8	222/8.8	23.5/52		
31HCT	31	12	310	180	625	—	330/13.0	172/6.8	238/9.4	25.7/57		
31-750	31	12	370*	160	750	—	330/13.0	172/6.8	238/9.4	24.5/54		
31-900	31	12	450*	160	900	—	330/13.0	172/6.8	238/9.4	25.2/55		
34-60	34	12	250	110	500	—	260/10.3	172/6.8	240/9.4	25.0/55		
41-50	41	12	250	80	510	—	292/11.5	172/6.8	173/6.8	18.3/36		
41-60	41	12	310	90	625	—	292/11.5	172/6.8	173/6.8	17.7/39		
42-50	42	12	190	70	390	—	229/9.0	172/6.8	222/8.8	18.0/40		
45-50	45	12	200	70	410	—	226/8.9	140/5.5	218/8.6	12.3/27		
46-5E	46	12	250	125	500	395	270/10.6	172/6.8	222/8.8	19.0/42		
49-4	24F	12	180	80	370	290	270/10.6	172/6.8	222/8.8	17.1/38		
49-5	24F	12	250	125	505	395	270/10.6	172/6.8	222/8.8	19.5/43		
49-5E	24F	12	250	125	500	395	270/10.6	172/6.8	222/8.8	19.5/43		
49-30	24F	12	130	60	275	210	270/10.6	172/6.8	222/8.8	15.8/35		
49-40	24F	12	150	75	300	230	270/10.6	172/6.8	222/8.8	16.0/35		
49-50	24F	12	180	80	370	290	270/10.6	172/6.8	222/8.6	17.1/38		
49-50A	49	12	310	155	630	—	381/15.0	174/6.8	168/6.7	NA		
49-60	24F	12	250	125	505	395	270/10.6	172/6.8	222/8.8	19.5/43		
54-5	22F	12	200	90	400	300	240/9.4	172/6.8	210/8.3	15.6/34		
55-4	22F	12	150	70	310	220	240/9.4	172/6.8	210/8.3	14.3/32		
55-5	22F	12	200	90	405	300	240/9.4	172/6.8	210/8.3	15.6/34		
55-5E	22F	12	200	90	405	300	240/9.4	172/6.8	210/8.3	15.6/34		
55-30	22F	12	130	60	265	200	240/9.4	172/6.8	210/8.3	13.8/30		
55-40	22F	12	140	65	280	225	240/9.4	172/6.8	210/8.3	13.8/30		
55-50	22F	12	150	70	310	220	240/9.4	172/6.8	210/8.3	14.3/32		
55-50A	55	12	210	75	430	—	212/8.3	154/6.0	218/8.6	NA		
55-60	22F	12	200	90	405	300	240/9.4	172/6.8	210/8.3	15.6/34		
55-60S	55	12	260	80	525	—	225/8.9	154/6.0	212/8.4	13.4/29		
58-4A	24	12	180	80	370	290	260/10.2	172/6.8	222/8.8	16.8/37		
58-5	24	12	250	125	500	395	260/10.2	172/6.8	222/8.8	19.5/43		

HANDOUT #1

FREEDOM BATTERY TEST SPECIFICATIONS

Cat No	BCI Group Size	Volts	Amps for Load Test	SAE — BCI Reserve Capacity (Minutes)	COLD CRANKING CURRENT SAE SPEC J537h @0°F (18°c) (in Amps)	@ 20°F (29°c) (in Amps)	MAXIMUM DIMENSIONS (MM IN) Length (incl Flanges)	Width	Height (incl Top Post)	APPROX WEIGHT KG/LBS Wet	Dry	ELECTROLYTE REQ D LITER/QTS
58-5A	24	12	250	125	500	395	260/10.2	172/6.8	222/8.8	19.2/42		
58-50	58	12	210	75	425	—				11.9/26		
58-60S	58	12	230	70	470	—	241/9.4	183/7.2	171/6.8	12.4/27		
59-4	24	12	180	80	370	290	260/10.2	172/6.8	222/8.8	17.1/38		
59-5	24	12	250	125	505	395	260/10.2	172/6.8	222/8.8	19.5/43		
59-5E	24	12	250	125	500	395	260/10.2	172/6.8	222/8.8	19.5/43		
59-30	24	12	130	60	275	200	260/10.2	172/6.8	222/8.8	15.8/35		
59-40	24	12	150	75	300	230	260/10.2	172/6.8	222/8.8	16.0/35		
59-50	24	12	180	80	370	290	260/10.2	172/6.8	222/8.8	17.1/38		
59-60	24	12	250	125	505	395	260/10.2	172/6.8	222/8.8	19.5/43		
59A-5E	24	12	270	135	540	—	260/10.2	172.6.8	222/8.8	19.1/42		
62-50A	62	12	200	75	400	—	218/8.6	161/6.4	224/8.8	NA		
62-60A	62	12	240	90	480	—	226/8.9	162/6.4	225/8.9	—		
70-5	27	12	250	125	500	395	305/12.0	172/6.8	222/8.8	21.3/47		
70-50	70	12	160	75	315	—	206/8.1	177/7.0	194/7.6	12.3/27		
70-60	70	12	200	80	410	—	206/8.1	177/7.0	194/7.6	13.1/29		
70-40S	70	12	180	60	370	—	206/8.1	177/7.0	194/7.6	12.2/27		
70-50S	70	12	220	70	440	—	206/8.1	177/7.0	194/7.6	12.3/27		
70-60S	70	12	260	80	525	-	206/8.1	177/7.0	194/7.6	13.7/30		
70DT72	—	12	320	80	650	—	215/8.4	177/7.0	201/7.9	14.7/32		
71-4	27	12	220	100	450	330	305/12.0	172/6.8	222/8.8	20.3/45		
71-5	27	12	250	125	505	395	305/12.0	172/6.8	222/8.8	21.3/47		
71-5E	27	12	250	125	500	295	305/12.0	172/6.8	222/8.8	21.3/47		
71-40	27	12	180	80	370	285	305/12.0	172/6.8	222/8.8	18.9/42		
71-50	27	12	220	100	450	330	305/12.0	172/6.8	222/8.8	20.3/45		
71-60	27	12	250	125	505	395	305/12.0	172/6.8	222/8.8	21.3/47		
71A-60	71	12	325	80	650	—	206/8.1	177/7.0	213/8.4	15.3/34		
71A-72	71	12	320	80	650	—	206/8.1	172/6.8	213/8.4	15.4/34		
71B-60	71	12	210	80	420	—	206/8.1	177/7.0	213/8.4	14.3/31		
73-50	73	12	210	80	420	—	230/9.1	172/6.8	213/8.4	15.2/33		
73-60	73	12	230	90	475	—	229/9.0	177/7.0	213/8.4	18.0/40		
74-40	74	12	180	75	370	—	260/10.2	177/7.0	213/8.4	15.0/33		
74-50	74	12	230	90	475	—	260/10.2	177/7.0	213/8.4	16.4/36		
74-60	74	12	280	95	525	—	260/10.2	177/7.0	213/8.4	17.7/39		
74A-60	74	12	290	110	560	—	260/10.2	177/7.0	213/8.4	19.0/42		
S74-60	74	12	260	95	525	—	259/10.3	177/7.0	203/[illegible]	NA		
S74A-60	74	12	260	105	525	—	260/10.2	172/6.8	213/8.4	17.7/39		
74MF	74	12	200	125	400	—	260/10.2	177/7.0	194/7.6	19.6/43		
75-60	75	12	250	90	525	400	229/9.0	177/7.0	183/7.2	15.0/33		
75A-60	75	12	310	90	630	500	229/9.0	177/7.0	194/7.6	15.1/33		
75A-72	75	12	310	90	630	500	229/9.0	177/7.0	194/7.8	15.5/34		
75MF60	75	12	250	95	500	—	229/9.0	177.7.0	183/7.3	15.0/33		
76-60	76	12	370	175	750	—	330/13.0	177/7.0	213/8.4	24.2/53		
76A-60	76	12	550	150	1075	—	330/13.0	177/7.0	213/8.4	24.9/54		
78A-72	76	12	540	150	1075	—	330/13.0	172/6.8	213/8.4	26.1/57		
78-60	78	12	270	115	550	—	260/10.2	177/7.0	194/7.6	16.9/37		
78A-60	78	12	380	115	770	—	260/10.2	177/7.0	194/7.6	17.2/38		
78A-72	78	12	380	115	770	—	260/10.2	172/[illegible]	194/7.6	18.0/40		
81-4	27F	12	220	100	450	330	316/12.4	172/6.8	222/8.8	20.3/45		
81-5	27F	12	250	125	505	395	316/12.4	172/6.8	222/8.8	21.3/47		
81-5E	27F	12	250	125	500	395	316/12.4	172/6.8	222/8.8	21.3/47		
81-40	27F	12	180	80	370	285	316/12.4	172/6.8	222/8.8	18.9/42		
81-50	27F	12	220	100	450	330	316/12.4	172/6.8	222/8.8	20.3/45		
81-60	27F	12	250	125	505	395	316/12.4	172/6.8	222/8.8	21.3/47		
83-50	—	12	150	75	315	235	206/8.1	177/7.0	194/7.6	13.2/29		
83-60	—	12	200	80	405	285	206/8.1	177/7.0	194/7.6	12.4/27		
84-4	71	12	130	60	275	210	206/8.1	177/7.0	213/8.4	12.7/28		
84-5	71	12	170	80	350	270	206/8.1	177/7.0	213/8.4	14.6/32		
85-4	71	12	130	60	275	210	206/8.1	177/7.0	213/8.4	12.7/28		
85-5	71	12	170	80	350	270	206/8.1	177/7.0	213/8.4	14.6/32		
85-5E	71	12	170	80	350	270	206/8.1	177/7.0	213/8.4	14.6/32		
85-50	71	12	130	60	275	210	206/8.1	177/7.0	213/8.4	13.6/30		
85-60	71	12	170	80	350	270	206/8.1	177/7.0	213/8.4	14.6/32		
85A-60	71	12	190	90	390	270	206/8.1	177/7.0	213/8.4	14.8/33		
85B-60	85	12	260	90	550	440	229/9.0	172/6.8	201/8.1	15.3/34		
86-5	73	12	210	100	430	330	229/9.0	177/7.0	213/8.4	17.1/38		
87-4	73	12	180	80	370	290	229/9.0	177/7.0	213/8.4	15.8/35		
87-5	73	12	210	100	430	330	229/9.0	177/7.0	213/8.4	17.1/38		
87-5E	73	12	210	100	430	330	229/9.0	177/7.0	213/8.4	17.1/38		
87-40	73	12	150	75	300	230	229/9.0	177/7.0	213/8.4	14.8/33		

HANDOUT #1

FREEDOM BATTERY TEST SPECIFICATIONS

Cat No	BCI Group Size	Volts	Amps for Load Test	SAE — BCI Reserve Capacity (Minutes)	COLD CRANKING CURRENT SAE SPEC J537h @0°F (-18°c) (in Amps)	@ -20°F (-29°c) (in Amps)	MAXIMUM DIMENSIONS (MM/IN) Length (incl Flanges)	Width	Height (incl Top Post)	APPROX WEIGHT KG/LBS Wet	Dry	ELECTROLYTE REQ'D LITER/QTS
87-50	73	12	180	80	370	290	229/9.0	177/7.0	213/8.4	15.8/35		
87-60	73	12	210	100	430	300	229/9.0	177/7.0	213/8.4	17.1/38		
87A-60	73	12	230	115	460	370	229/9.0	177/7.0	213/8.4	17.8/39		
88-5	74	12	230	125	465	375	260/10.2	177/7.0	213/8.4	19.5/43		
88A-5	74	12	270	135	540	435	260/10.2	177/7.0	213/8.4	20.5/45		
89-4	74	12	180	80	370	290	260/10.2	177/7.0	213/8.4	17.0/37		
89-5	74	12	250	125	505	395	260/10.2	177/7.0	213/8.4	19.5/43		
89-5E	74	12	250	125	500	395	260/10.2	177/7.0	213/8.4	19.5/43		
89-30	74	12	130	60	275	210	260/10.2	177/7.0	213/8.4	15.8/35		
89-40	74	12	150	75	300	230	260/10.2	177/7.0	213/8.4	16.0/35		
89-50	74	12	180	80	370	290	260/10.2	177/7.0	213/8.4	17.0/37		
89-60	74	12	250	125	505	395	260/10.2	177/7.0	213/8.4	19.5/43		
89A-5	74	12	270	135	540	440	260/10.2	177/7.0	213/8.4	20.5/45		
89A-5E	74	12	270	135	540	440	260/10.2	177/7.0	213/8.4	20.5/45		
89A-60	74	12	270	135	540	440	260/10.2	177/7.0	213/8.4	20.5/45		
042	26	12	200	70	410	—	206/8.1	172/6.8	202/8.0	13.3/29		
043	24	12	180	115	375	—	260/10.2	172/6.8	222/8.8	19.9/44		
044	27	12	240	160	480	—	305/12.0	172/6.8	222/8.8	23.[illegible]/52		
087	(C)	12	170	60	350		279/11.0	172/6.8	203/8.0	19.3/42		
	(A)	12	100	45	230							
099	70	12	150	75	315	235	206/8.1	177/7.0	194/7.6	12.4/27		
101	70	12	150	60	310	230	206/8.1	177/7.0	194/7.6	11.7/25		
102	73	12	170	70	355	270	206/8.1	177/7.0	194/7.6	12.4/27		
103	70	12	200	75	405	305	206/8.1	177/7.0	194/7.6	12.7/28		
104	75	12	250	90	500	400	229/9.0	177/7.0	194/7.6	14.9/33		
105	78	12	250	115	515	415	260/10.2	177/7.0	194/7.6	16.8/36		
106	78	12	270	115	550	440	260/10.2	177/7.0	194/7.6	16.9/37		
107	78	12	380	115	770	—	260/10.2	177/7.0	194/7.6	17.2/38		
108	76	12	370	175	750	600	330/13.0	177/7.0	213/8.4	24.1/53		
110	71	12	190	90	390	315	206/8.1	177/7.0	213/8.4	14.4/32		
129	24	12	190	100	390	—	285/11.2	178/7.0	251/9.8	NA		
137	70	12	270	80	550	—	206/8.1	177/7.0	194/7.6	13.1/29		
140	76	12	550	155	1075	—	330/13.0	177/7.0	213/8.4	24.9/54		
157	73	12	230	115	465	375	229/9.0	177/7.0	213/8.4	16.9/37		
183	74	12	270	135	550	440	260/10.2	177/7.0	213/8.4	19.1/42		
296	75	12	315	90	630	500	229/9.0	177/7.0	194/7.6	15.1/33		
320	75	12	250	90	500	400	229/9.0	177/7.0	194/7.6	14.8/33		
515	35	12	150	90	310	—	229/9.0	172/6.8	222/8.8	15.3/34		
577	70	12	260	75	525	—	206/8.1	172/6.8	194/7.6	13.2/29		
581	78	12	310	105	620	—	260/10.2	172/6.8	194/7.6	17.1/38		
MP594	24	12	160	65	325	—	260/10.2	172/6.8	222/8.8	15.2/33		
MP596	24	12	260	105	525	—	260/10.2	172/6.8	222/8.8	17.9/40		
600	70	12	260	75	525	—	206/8.1	172/6.8	183/7.1	13.3/29		
601	75	12	310	90	630	—	229/9.0	172/6.8	183/7.1	15.5/34		
602	78	12	330	115	770	—	260/10.2	172/6.8	194/7.6	17.9/40		
607	75	12	280	90	570	—	229/9.0	172/6.8	194/7.6	14.8/33		
608	78	12	360	115	730	—	260/10.2	172/6.8	194/7.6	17.5/39		
810	75	12	210	90	430	—	229/9.0	172/6.8	194/7.6	14.3/31		
611	75	12	310	90	630	490	229/9.0	177/7.0	194/7.6	15.5/34		
691	70	12	130	58	260	200	206/8.1	177/7.0	194/7.6	11.5/25		
692	70	12	150	75	315	235	206/8.1	177/7.0	194/7.6	13.4/29		
693	70	12	180	80	370	285	206/8.1	177/7.0	194/7.6	13.2/29		
694	71	12	170	90	350	270	206/8.1	177/7.0	213/8.4	14.8/33		
695	73	12	230	115	460	370	229/9.0	177/7.0	213/8.4	17.8/39		
696	74	12	270	140	550	435	260/10.2	177/7.0	213/8.4	20.2/45		
726	70	12	160	60	330	255	206/8.1	177/7.0	183/7.2	11.2/25		
727	70	12	190	70	385	300	206/8.1	177/7.0	183/7.2	12.2/27		
728	70	12	210	75	425	330	206/8.1	177/7.0	183/7.2	12.3/27		
729	75	12	210	90	430	330	229/9.0	177/7.0	183/7.2	14.2/31		
730	75	12	260	90	525	405	229/9.0	177/7.0	183/7.2	14.9/33		
731	75	12	280	90	570	140	229/9.0	177/7.0	183/7.2	15.2/33		
732	75	12	310	90	630	[illegible]90	229/9.0	177/7.0	183/7.2	15.5/34		
733	78	12	270	115	540	410	260/10.2	177/7.0	183/7.2	16.6/37		
734	78	12	310	115	630	490	260/10.2	177/7.0	183/7.2	17.1/38		
735	78	12	360	115	730	550	260/10.2	177/7.0	183/7.2	18.0/40		
736	78	12	380	115	770	600	260/10.2	177/7.0	183/7.2	18.0/40		
858	75	12	220	90	500	—	229/9.0	176/6.9	194/7.6	14.9/33		
MP894	74	12	160	65	325	—	260/10.2	172/6.8	213/8.4	15.0/33		
MP896	74	12	260	105	525	—	260/10.2	172/6.8	213/8.4	17.7/39		
[illegible]30	78	12	370	175	750	—	330/13.0	177/7.0	213/8.4	24.2/53		

HANDOUT #1

FREEDOM BATTERY TEST SPECIFICATIONS

Cat No	BCI Group Size	Volts	Amps for Load Test	SAE — BCI Reserve Capacity (Minutes)	COLD CRANKING CURRENT SAE SPEC J537h @0 F (-18 C) (in Amps)	@-20 F (-29 C) (in Amps)	MAXIMUM DIMENSIONS (MM IN) Length (incl Flanges)	Width	Height (incl Top Post)	APPROX WEIGHT KG LBS Wet	Dry	ELECTROLYTE REQ'D LITER/QTS
1059	24	12	180	115	375	—	260/10.2	172/6.8	222/8.8	19.9/44		
1059E	24	12	180	115	375	—	260/10.2	172/6.8	222/8.8	19.9/44		
1071	27	12	240	160	480	—	305/12.0	172/6.8	222/8.8	23.6/52		
1071E	27	12	240	160	480	—	305/12.0	172/6.8	222/8.8	23.6/52		
1089	74	12	180	115	375	—	260/10.2	177/7.0	213/8.4	19.7/43		
1110	31	12	310*	160	625	490	330/13.0	172/6.8	238/9.4	24.1/53		
1111	31	12	310	160	625	490	330/13.0	172/6.8	238/9.4	24.2/53		
1150	31	12	290*	180	580	—	330/13.0	172/6.8	238/9.4	27.4/60		
1150	31	12	310*	180	625	—	330/13.0	172/6.8	238/9.4	25.5/56		
1151	31	12	290	180	580	—	330/1[illegible]	172/6.8	238/9.4	27.1/60		
1151	31	12	310	180	625	—	330/13.0	172/6.8	238/9.4	25.6/56		
1151S	31	12	310	180	625	490	330/13.0	172/6.8	240/9.4	26.0/57		
1200	31	12	230*	130	475	375	330/13.0	172/6.8	238/9.4	23.9/53		
1200	31	12	270*	130	550	—	330/13.0	172/6.8	238/9.4	22.4/49		
1200D	31	12	270*	130	550	—	330/13.0	172/6.8	240/9.5	22.6/50		
1200E	31	12	230*	130	475	375	330/13.0	172/6.8	238/9.4	23.9/53		
1200E	31	12	270*	130	550	—	330/13.0	172/6.8	238/9.4	23.9/53		
1201	31	12	230	130	475	375	330/13.0	172/6.8	238/9.4	23.4/51		
1201	31	12	270	130	550	—	330/13.0	172/6.8	238/9.4	22.7/50		
1210E	31	12	310*	160	625	490	330/13.0	172/6.8	238/9.4	26.9/59		
1210E	31	12	310*	160	625	—	330/13.0	172/6.8	238/9.4	25.9/57		
1250E	31	12	290*	180	580	—	330/13.0	172/6.8	238/9.4	27.4/60		
1251E	31	12	290	180	580	—	330/13.0	172/6.8	238/9.4	27.4/60		
2000	31	12	—	180	580	—	330/13.0	172/6.8	238/9.4	27.4/60		
2000	31	12	—	180	580	—	330/13.0	172/6.8	238/9.4	26.8/59		
S2000	31	12	290	180	580	—	330/13.0	172/6.8	240/9.4	26.8/63		

*Battery tester cable clamps should be between terminal nuts and lead pads of terminals. If not possible, load value should be 330 amperes for 31-750, 405 amperes for 31-900, 275 amperes for 1110, 1150, 1250E & 1210E, and 240 amperes for 12[illegible]0 & 1200E.

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STORAGE BATTERIES
UNIT IV

HANDOUT #2 — COLD CRANKING AMPS FOR CONVENTIONAL BATTERIES

FILLER-CAP BATTERY TEST SPECIFICATIONS

Cat No	BCI Group Size	Volts	Amps for Load Test	SAE — BCI Reserve Capacity (Minutes)	COLD CRANKING CURRENT SAE SPEC J537h @0 F (-18 C) (in Amps)	@-20 F (-29 C) (in Amps)	MAXIMUM DIMENSIONS (MM IN) Length (incl Flanges)	Width	Height (incl Top Post)	APPROX WEIGHT KG LBS Wet	Dry	ELECTROLYTE REQ'D LITERS/QTS
A31E	31	12	450	160	900	—	330/13.0	172/6.8	240/9.4	25.0/55		
FD1	NS	12	NA	NA	NA	—	419/16.5	179/7.1	281/11.1	44/97	32/71	9.8/10.4
FD2	3EH	6	420	340	850	—	482/19.3	108/4.3	250/9.8	27.3/60	20.0/44	6.4/6.8
M24	24	12	190	100	390	—	285/11.1	178/7.0	250/9.8	NA		
Y51A		12	190	75	380	—	217/8.6	153/6.0	212/8.5	15.0/33	11.0/25	3.2/3.4
Y63A	60	12	160	95	330	—	328/12.9	156/6.1	226/8.9	21.1/46	17.0/37	3.4/3.6
Y65A	28NF	12	140	80	290	—	330/13.0	140/5.5	226/8.9	19.3/42	15.0/33	3.4/3.8
Z03	17L	6	200	110	405	325	184/7.2	168/6.6	188/7.4	10.9/24	8.2/18	2.6/2.8
Z13	1M1	6	190	105	390	310	226/8.9	176/6.9	218/8.6	14.5/32	9.1/20	4.2/4.5
347	NS	12	80	31	160	—	197/7.7	131/5.2	185/7.3	8.8/20	8.8/15	1.9/2.0
349	NS	12	95	31	194	—	197/7.7	131/5.2	185/7.3	9.8/22	7.7/17	1.7/1.8
351	22NF	12	120	52	240	—	239/9.4	140/5.5	225/8.8	14.1/31	10.0/22	3.3/3.5
353	NS	12	95	31	194	—	211/8.3	132/5.2	188/7.4	9.5/21	6.8/15	1.9/2.0
361A	3ET	12	200	120	400	—	488/19.5	108/4.3	248/9.9	25.4/56	21.8/48	2.8/3.0
4-800	4	6	400	270	800	—	333/13.1	181/7.2	238/9.4	NA		
4-800A	4	8	400	270	800	—	333/13.1	181/7.2	238/9.4	NA		
403	7L1	6	210	130	415	375	185/7.3	169/6.6	188/7.4	11.8/26	9.1/20	2.3/2.4
405A	19L	6	220	140	450	—	207/8.1	168/6.6	189/7.4	12.7/28	10.2/23	1.9/2.0
411A	1	6	245	180	490	—	222/8.7	168/6.6	224/8.8	16.8/37	13.2/29	2.8/3.0
413	1M1	6	205	145	410	330	229/9.0	178/7.0	218/8.6	16.3/36	11.3/25	4.2/4.4
413A	1	8	200	145	410	—	222/8.7	168/6.6	224/8.8	15.4/34	11.8/26	2.8/3.0
417	1M2	6	235	165	475	380	262/10.3	178/7.0	218/8.6	18.6/41	13.2/29	4.5/4.8
417A	2	6	270	165	550	—	257/10.1	170/6.7	225/8.9	20.0/44	16.3/36	3.0/3.2
419A	2E	8	270	165	550	—	484/19.4	99/4.0	224/8.8	19.0/42	14.5/32	3.8/4.0
461A	3EE	12	180	95	380	—	488/19.5	108/4.3	224/8.8	22.2/49	17.2/38	3.8/4.0
553	—	12	130	50	280	—	240/9.4	174/6.9	172/6.8	14.1/31	10.4/23	3.8/4.0
557A	53	12	120	80	240	—	327/13.1	117/4.7	210/8.4	15.6/34	13.2/29	1.9/2.0
713A	3	6	270	250	550	440	292/11.7	178/7.1	234/9.4	23.2/51	15.9/35	5.8/8.1
715A	4	6	265	245	530	—	227/8.9	174/6.8	229/9.0	25.8/57	19.5/43	5.7/6.0
717A	4	6	370	270	750	—	327/12.9	173/6.9	229/9.2	24.9/55	16.9/37	6.4/6.8
719A	7D	6	450	375	900	—	406/16.0	178/7.1	230/9.1	32.6/72	24.5/54	6.6/7.0
721A	4DLT	12	370	250	750	—	506/19.9	206/8.1	204/8.0	40.8/90	32.6/72	7.6/8.1
725A	5D	6	410	340	830	675	343/13.7	181/7.2	234/9.4	27.8/61	20.3/45	5.7/6.0
759A	4D	12	300	430	875	—	516/20.3	220/8.7	248/9.8	55.[illegible]/122	40.8/90	11.4/12.1
761A	8D	12	450	400	1050	—	526/20.7	266/10.5	250/9.8	85.9/145	46.4/102	15.5/16.4
781AA	8D	12	520	375	1050	—	525/20.7	278/10.9	248/9.8	NA		
771A	8D	12	520	375	1050	—	527/20.7	283/11.1	276/10.8	NA		
775A	30H	12	210	160	575	—	342/13.5	170/6.7	232/9.1	26.8/63	23.1/51	4.5/4.8
8V1	—	8	180	120	360	280	226/8.9	173/6.8	224/0.8	16.8/37	11.4/25	4.2/4.4
8V2	—	8	200	140	410	330	264/10.4	178/7.0	226/8.9	19.5/43	14.1/31	4.5/4.8
801A	—	8	220	160	440	—	330/13.0	172/6.8	238/9.4	25.4/56	18.4/40	7.4/7.8
821A	—	8	210	275	425	—	544/21.4	176/6.9	252/9.9	53.5/118	40.4/89	10.6/11.2
823	75	12	250	90	500	380	229/9.0	177/7.0	194/7.6	15.0/33		
826	75	12	250	90	500	375	229/9.0	177/7.0	183/7.2	15.0/33		
831A(ord)	2HN	12	130	—	—	—	260/10.2	134/5.3	230/9.1	15.4/34	11.3/25	3.4/3.6
837A(ord)	8TN	12	300	—	—	—	284/11.2	268/10.6	230/9.1	31.8/70	23.1/51	8.6/7.0
843A	GC2	6	—	—	—	—	260/10.2	178/7.0	270/10.6	29.5/65	25.8/57	2.8/3.0
845A	GC2	6	NA	105	NA	—	259/10.2	178/7.0	270/10.9	28.1/62	24.9/55	2.8/3.0

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STORAGE BATTERIES
UNIT IV

JOB SHEET #1 — TROUBLESHOOT A BATTERY

A. Tools and materials

1. Battery
2. Safety glasses
3. Rubber gloves
4. Rubber apron
5. Job Sheet #2
6. Job Sheet #3
7. Job Sheet #4

B. Procedure

(NOTE: Specific test procedures are required to determine the ability of a battery to function properly. For this reason, visual inspection, specific gravity check, and load test are sometimes required.)

1. Visual inspection

   a. Check for obvious damage such as a cracked or broken case.

   b. If damage is obvious, replace battery.

      (NOTE: Refer to Job Sheet #2.)

   c. If there is no obvious damage, check electrolyte level. If you have a battery, proceed to Step 3.

   d. If electrolyte level is above top of plates, proceed to Step 2.

   e. If electrolyte is below top of plates in one or more cells, add water to just above the separators. Charge for 15 minutes at 15-25 amps and then proceed to Step 2.

JOB SHEET #1

2. Test specific gravity on conventional batteries.

   (NOTE: Refer to Job Sheet #3.)

   a. Less than 50 points variation between highest and lowest cell, proceed to Step 4.

   b. 50 points or more variation between highest and lowest cell, replace battery.

      (NOTE: Refer to Job Sheet #2.)

3. Test specific gravity for maintenance-free batteries.

   a. Batteries without built-in hydrometer, go to Step 4.

   b. Batteries with built-in hydrometer, check color of indicator.

      1) Light yellow or white — Replace battery.

      2) Indicator is dark — Charge until indicator turns green, then connect 300 amp load for 15 seconds and proceed to step 4.

         (NOTE: For 300 amp load, refer to Job Sheet #4.)

      3) Green — Proceed to Step 4.

4. Load test the battery.

   a. Obtain specifications for the battery you are testing.

      Manufacturer's specifications:

      ____________ amps ____________ volts

   b. Obtain instructor's initials here ____________ before proceeding to next step.

   c. Connect voltmeter and proper load from specification for 15 seconds.

      (NOTE: Refer to Job Sheet #4.)

   d. If voltage is at or above chart value, return to service.

      (NOTE: Refer to Handouts #1 and 2 for charts.)

   e. If voltage is below chart value, replace battery.

      (NOTE: Maintenance-free batteries without built-in hydrometers must be given a long, slow charge and load tested again.)

STORAGE BATTERIES
UNIT IV

JOB SHEET #2 — REMOVE, SERVICE, AND REPLACE BATTERY

A. Tools and materials

1. Vehicle
2. Safety glasses
3. Rubber apron
4. Bristle brush
5. Wire brush
6. Screwdriver
7. Battery clamp puller
8. Combination end wrenches
9. Battery pliers
10. Baking soda and water solution (two tablespoons of baking soda to one pint of water)
11. Battery anti-corrosion paste
12. Battery post and cable cleaner
13. Shop towels
14. Torque wrench
15. Battery lift strap
16. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

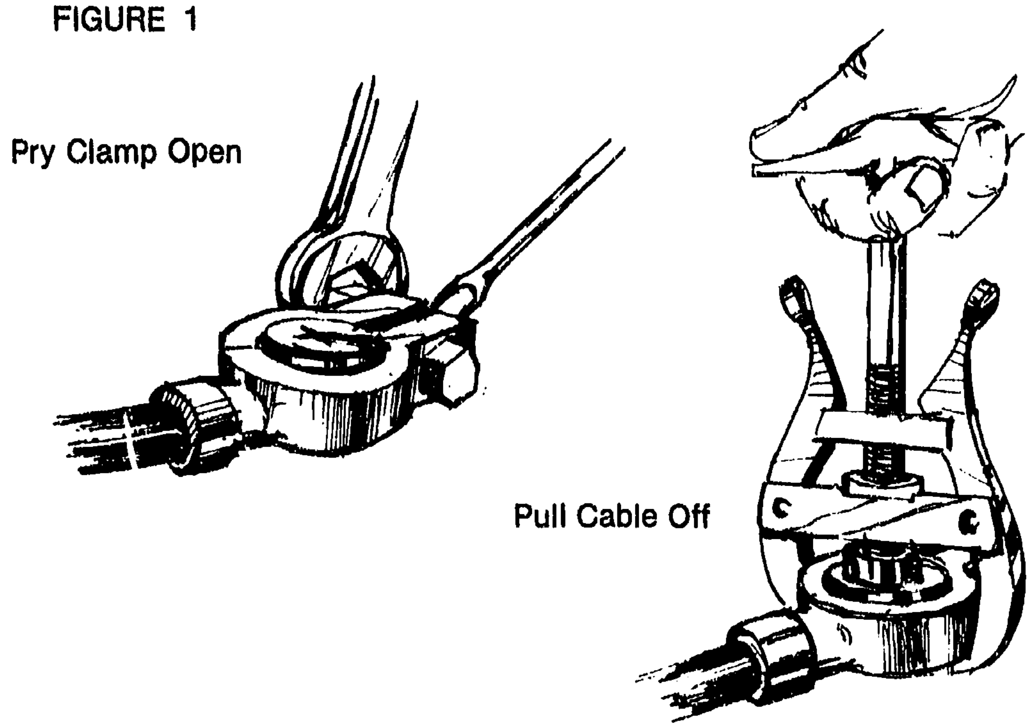
(NOTE: Observe the location of the positive post so the battery can be installed in the same way.)

JOB SHEET #2

1. Disconnect the battery cables from the battery posts. (Figure 1)

   (NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

   FIGURE 1



2. Remove the battery hold-down.

3. Remove the battery from the carrier.

   (NOTE: Use a suitable battery lift strap to lift the battery.)

4. Inspect the battery carrier for dirt or corrosion.

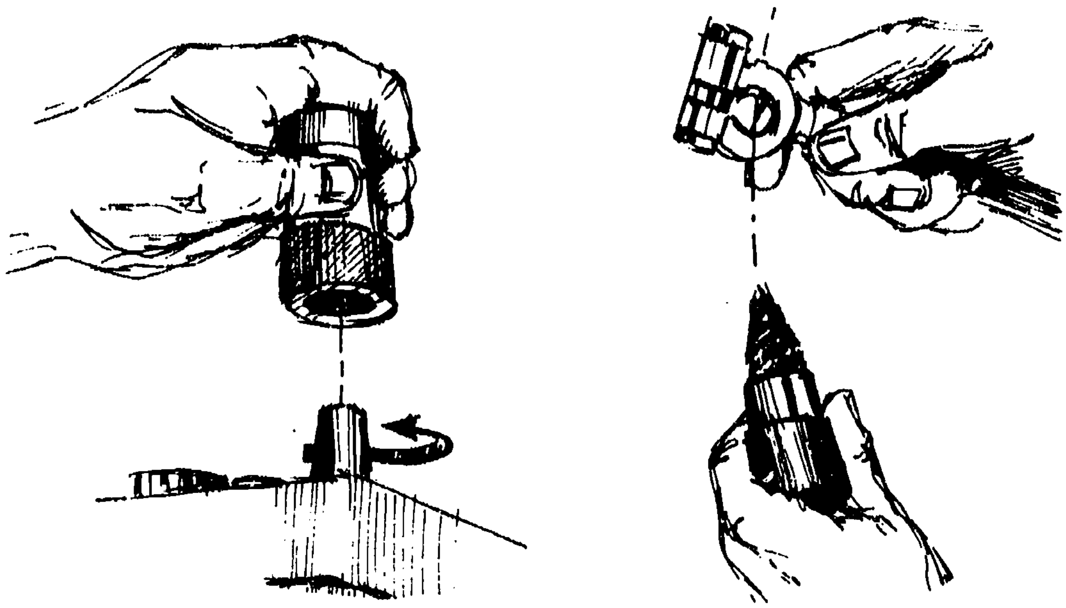
5. Check battery cables for worn or frayed insulation.

JOB SHEET #2

6. Clean battery cable clamps and battery post. (Figure 2)

   (NOTE: Battery posts and inside of battery cable clamps must be clean and bright.)

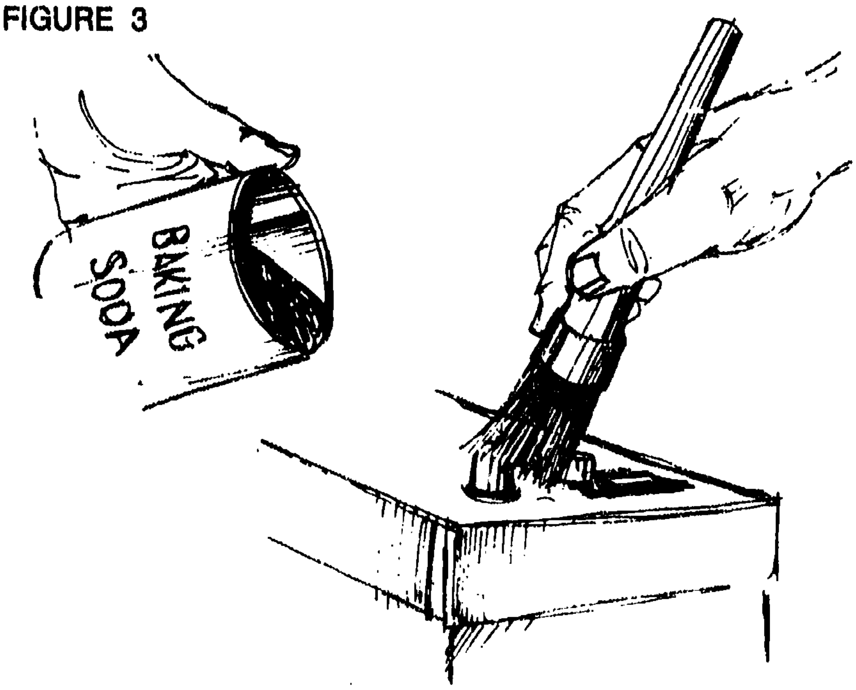
   FIGURE 2



7. Brush soda water solution on battery, battery post, clamps, and battery hold-down. (Figure 3)

   (NOTE: Keep water and soda from entering the battery through the vent holes in the vent caps.)

   FIGURE 3

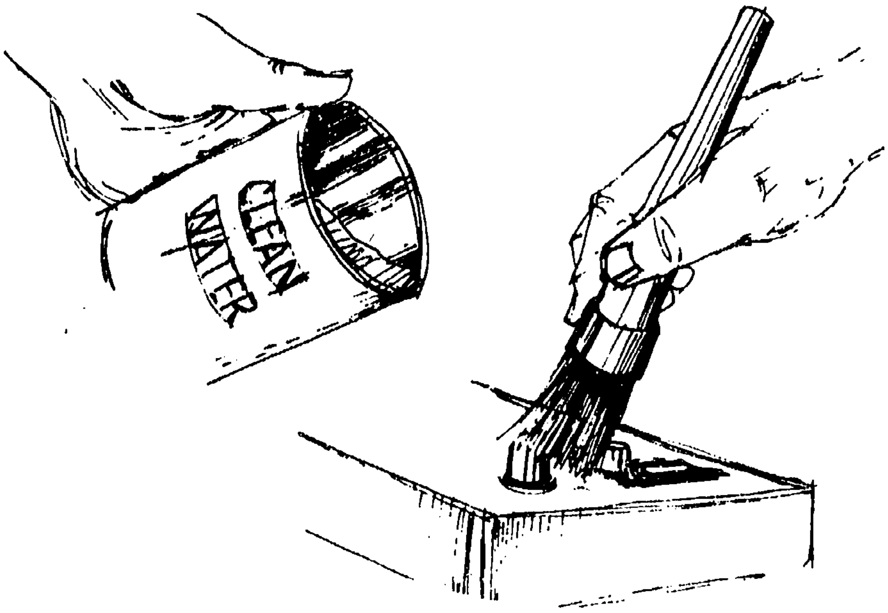


JOB SHEET #2

8. Wash away residue with clean water. (Figure 4)

   (NOTE: Remove all residue that may have lodged around battery, frame, or parts of the vehicle.)

   FIGURE 4



9. Set the battery into place using a lift strap.

   (NOTE: Position the battery to allow for correct battery cable attachment.)

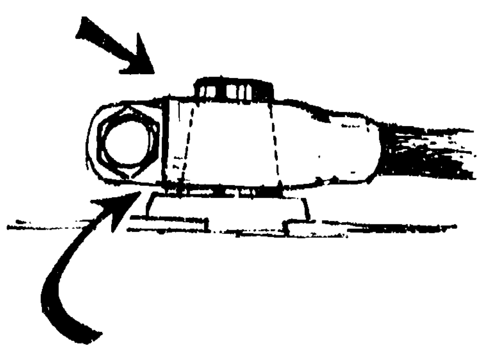
10. Install the battery hold-down clamp or strap and tighten securely.

11. Reconnect battery cables to the battery posts. (Figures 5 and 6)

    (NOTE: Always reconnect the insulated cable first and the ground cable last. Replace clamp bolts and nuts as needed.)

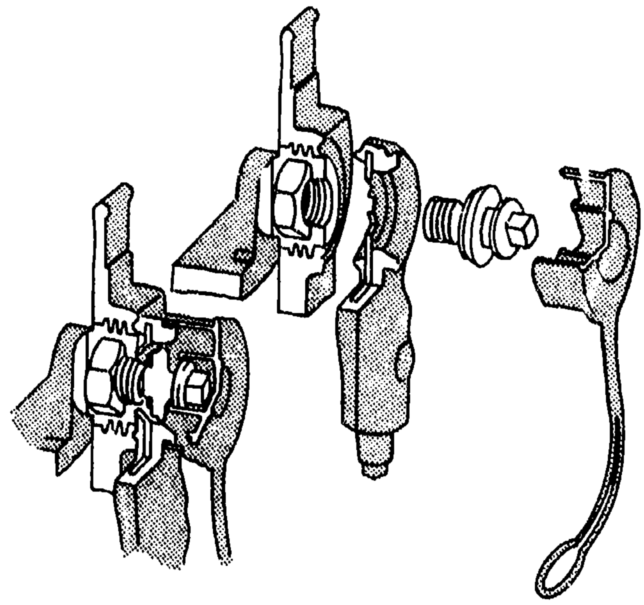
    (CAUTION: Do not hammer or force terminal on post as battery cover breakage may result.)

    FIGURE 5



JOB SHEET #2

FIGURE 6



Side Post Terminals

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(NOTE: Side post terminal bolts need to be torqued to manufacturer's specifications.)

12. Torque or tighten the battery clamps securely.

    (NOTE: Use care to avoid twisting the cable post.)

13. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals.

STORAGE BATTERIES
UNIT IV

JOB SHEET #3 — MEASURE SPECIFIC GRAVITY OF A CONVENTIONAL BATTERY

A. Tools and materials

1. Battery
2. Hydrometer
3. Shop towels
4. Container of clear water
5. Safety glasses
6. Rubber gloves
7. Rubber apron
8. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove vent caps from battery.
2. Insert the hydrometer into the first cell.
3. Squeeze the rubber bulb to draw electrolyte into the hydrometer to suspend the float.

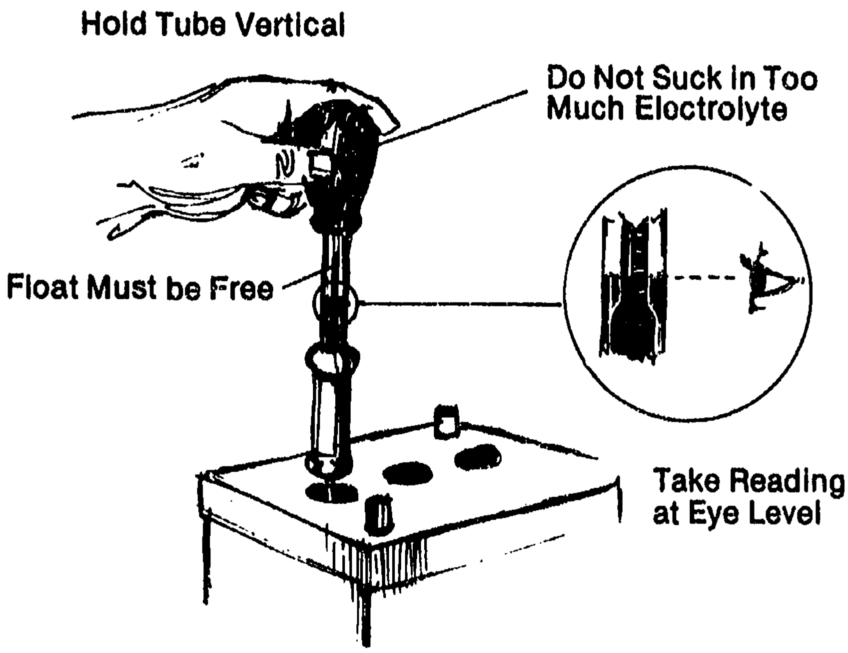
   (NOTE: If the electrolyte level is too low, add water, charge for one hour, and recheck.)

JOB SHEET #3

4. Take reading at eye level. (Figure 1)

   (NOTE: Make sure the float is not bumping the top of the hydrometer tube or sticking to the side of the tube; write down reading for each cell.)

   FIGURE 1



5. Squeeze bulb to return electrolyte to cell.

6. Repeat for other cells.

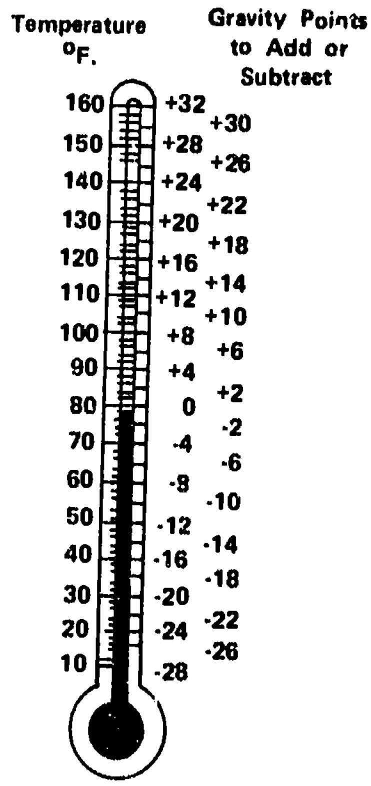
JOB SHEET #3

7. Adjust the readings for temperature.

   a. Add four gravity points (0.004) to the reading for every 10°F above 80°. Subtract four gravity points (0.004) for each 10° below 80°F. (Figure 2)

   FIGURE 2

   TEMPERATURE ADJUSTMENT CHART



   b. Check specific gravity; it should read from 1.215 to 1.270 (corrected to 80°F electrolyte temperature).

   c. Check the variation in readings between cells; it should be no more than 0.050.

   d. Charge and retest the battery if the readings are not within the above mentioned range.

8. Replace vent caps upon completion of test.

9. Flush any spilled electrolyte with clean water.

STORAGE BATTERIES
UNIT IV

JOB SHEET #4 — LOAD TEST A BATTERY

A. Tools and materials

1. Battery
2. Battery capacity tester
3. Appropriate conductors
4. Safety glasses
5. Rubber gloves
6. Rubber apron
7. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Check service manual to find the recommended load current to test a particular battery.

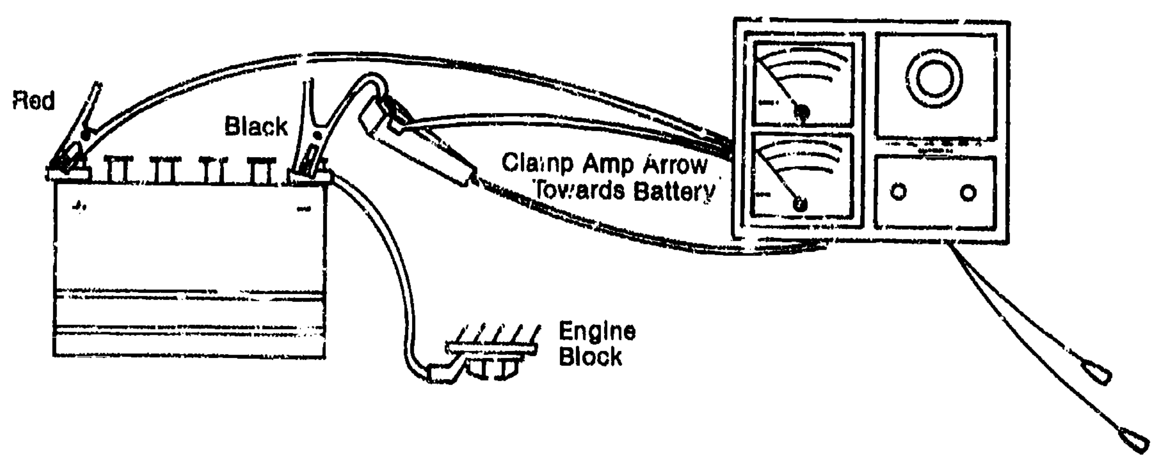
   Manufacturer's specifications:

   ____________ amps ____________ volts

   Obtain instructor's initials here ____________ before proceeding to next step.

2. Connect tester. (Figure 1)

   FIGURE 1



JOB SHEET #4

3. Turn the rheostat knob clockwise until the desired load is reached.

4. Apply load equal to three times the ampere-hour rating of battery being tested or ½ cold cranking amps.

   (NOTE: Ampere-hour rating should be marked on the outside of battery case. Refer to Handouts #1 and 2 for cold cranking amps.)

5. Read battery voltage at the end of 15 seconds.

   (NOTE: If voltage drops below 1.5 volts per cell in 15 seconds, use the 3-minute charge test.)

6. Loosen rheostat to relieve load at end of 15 seconds.

7. Disconnect tester.

STORAGE BATTERIES
UNIT IV

JOB SHEET #5 — CHARGE TEST A BATTERY FOR THREE MINUTES

A. Tools and materials

1. Battery
2. Adjustable, fast-rate battery charger
3. Battery capacity tester
4. Appropriate conductors
5. Safety glasses
6. Rubber gloves
7. Rubber apron
8. Appropriate service manual

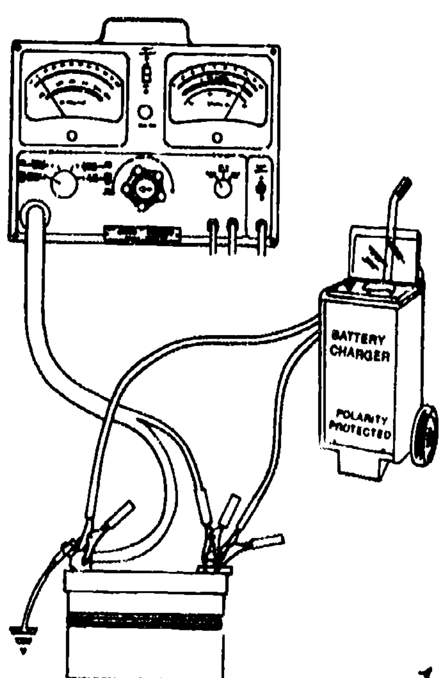
B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

(NOTE: Use charge test only on batteries that fail the capacity test. Do not use this test on maintenance-free batteries.)

1. Connect tester and charger. (Figure 1)

FIGURE 1



JOB SHEET #5

2. Turn charger on and adjust the charging rate to 40 amps for 12-volt batteries, 75 amps for 6-volt batteries.

3. Charge battery for 3 minutes.

4. Read individual cell voltages with battery charger still in operation.

   (NOTE: If they vary by more than 0.1 volt, replace battery.)

5. Read total battery voltage.

   (NOTE: If it is over 15.5 volts for 12-volt batteries or 7.75 for 6-volt batteries, the battery is unsatisfactory and must be given a long, slow charge and load-tested again. If voltage under load test is less than 9.5 volts (12-volt) or 4.8 volts (6-volt), replace battery.)

STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #1 — TROUBLESHOOT A BATTERY

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety equipment.	______	______
3. Visually inspected battery.	______	______
4. Checked specific gravity.	______	______
5. Obtained the correct manufacturer's specifications.	______	______
6. Load tested the battery.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Determined battery condition				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #2 — REMOVE, SERVICE, AND REPLACE BATTERY

STUDENT'S NAME ______________________________ DATE ______________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety equipment.	______	______
3. Disconnected battery cables using the proper tools.	______	______
4. Inspected battery carrier.	______	______
5. Checked battery cables.	______	______
6. Cleaned battery, battery clamps, and terminals.	______	______
7. Installed battery, battery hold-down clamps, and reconnected battery terminals.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Battery or batteries are installed correctly.				
	4	3	2	1
Battery, battery hold-down clamps, and battery terminals are clean and in good working order.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #3 — MEASURE SPECIFIC GRAVITY OF A CONVENTIONAL BATTERY

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety equipment.	______	______
3. Took specific gravity reading.	______	______
4. Adjusted the reading for temperature.	______	______
5. Flushed any spilled electrolyte with clean water.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Accuracy of specific gravity reading				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #4 — LOAD TEST A BATTERY

STUDENT'S NAME ______________________________ DATE ______________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety equipment.	______	______
3. Obtained battery specifications.	______	______
4. Connected and operated tester correctly.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Evaluation of test results				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STORAGE BATTERIES
UNIT IV

PRACTICAL TEST
JOB SHEET #5 — CHARGE TEST A BATTERY FOR THREE MINUTES

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	____	____
2. Used safety equipment.	____	____
3. Connected tester and charger to battery correctly.	____	____
4. Selected the correct amperage on charger.	____	____
5. Read total battery voltage to make evaluation of the battery.	____	____
6. Checked in/put away tools and materials.	____	____
7. Cleaned the work area.	____	____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Evaluation of test results				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STORAGE BATTERIES
UNIT IV

NAME ______________________ SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Two or more connected cells which convert chemical energy into electrical energy	1. Battery
_____b.	One positive plate group and one negative plate group	2. Cell
_____c.	Similar plates welded to a plate strap	3. Electrolyte
_____d.	Solution of water and sulfuric acid	4. Hydrometer
_____e.	Weight of electrolyte compared to an equal volume of water at 60°F	5. Plate group
_____f.	A test instrument for determining the specific gravity of electrolyte	6. Specific gravity
_____g.	Oxidation of positive plate grid wires and formulation of lead sulfate crystals which become dense and hard	7. Sulfated

2. List three functions of a battery.

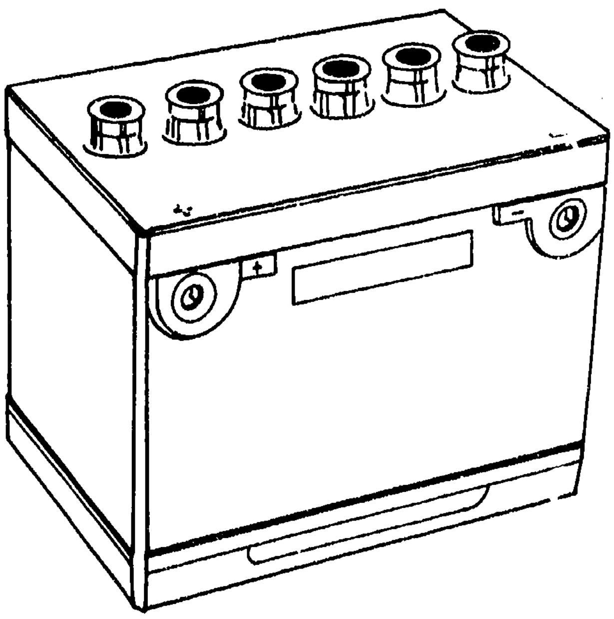
   a. ____

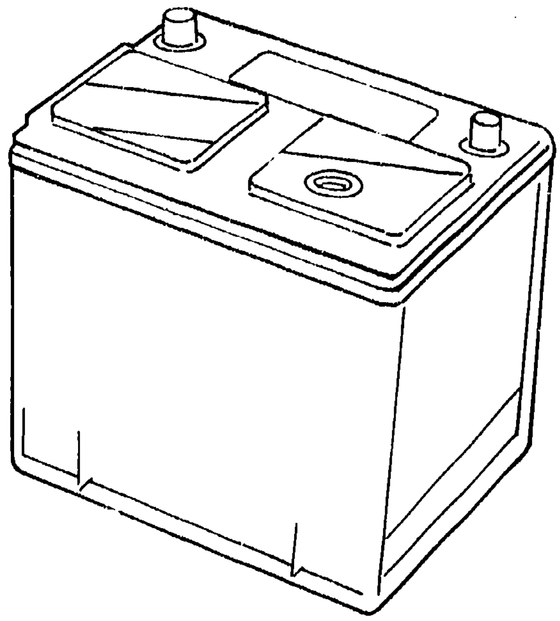
   b. ____

   c. ____

TEST

3. Identify the following types of batteries.





a. ______________________ b. ______________________

4. Distinguish between the characteristics of batteries by placing a "C" next to the characteristics of conventional batteries and an "M" next to the characteristics of maintenance-free batteries.

_____a. Lifetime supply of electrolyte

_____b. Less gassing and corrosion

_____c. Vent caps are used for each cell

_____d. Longer shelf life

_____e. Built-in hydrometer

_____f. Electrolyte level has to be checked and water added to each cell

_____g. Withstand more vibration

_____h. Resist overcharging

5. Complete the following statements concerning the voltage ratings of batteries by placing the correct number(s) in the blanks. Choose your answers from the following numbers: 3, 6, 9, 12.

a. 6-volt batteries have __________ cells.

b. 12-volt batteries have __________ cells.

TEST

6. Distinguish between amp hour rating and cold cranking amps by placing an "X" next to the description of cold cranking amps.

   _____a. Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time

   _____b. Number of amps that can be taken from a fully charged battery at 0°F for 30 seconds

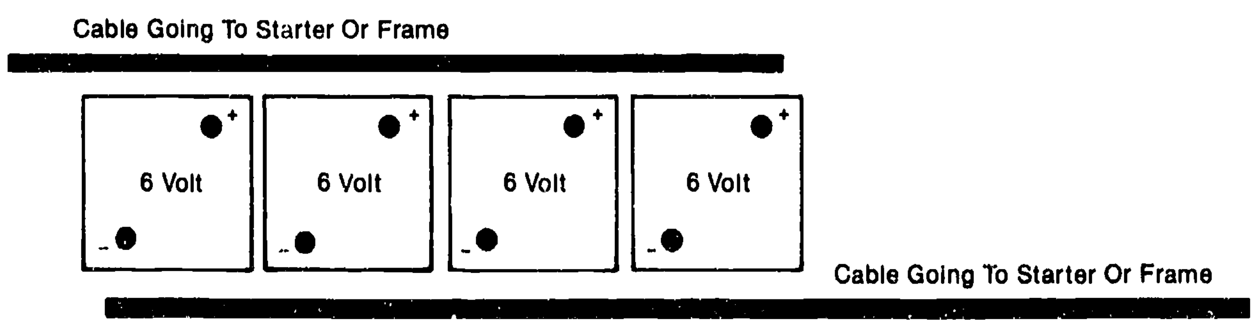
7. Complete the following statements concerning rules for installing batteries by inserting the correct word (on the right) that best completes each statement.

a.	Install only ___________ charged batteries.	Older
		Polarity
b.	Do not install a new battery alongside ___________ batteries.	Different
c.	Do not install batteries of ___________ capacities.	Fully
d.	Check ___________ of the vehicle.	

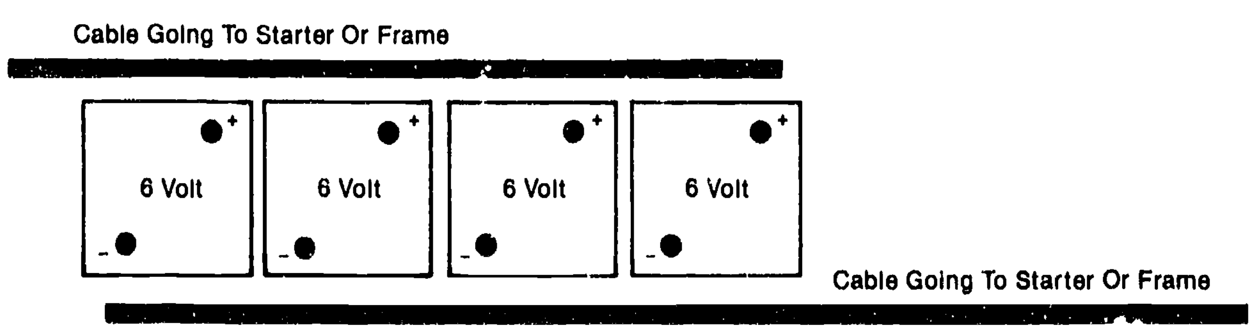
8. Draw lines showing the installation of battery cables.

   a. 6-volt batteries

      1) 12-volt system



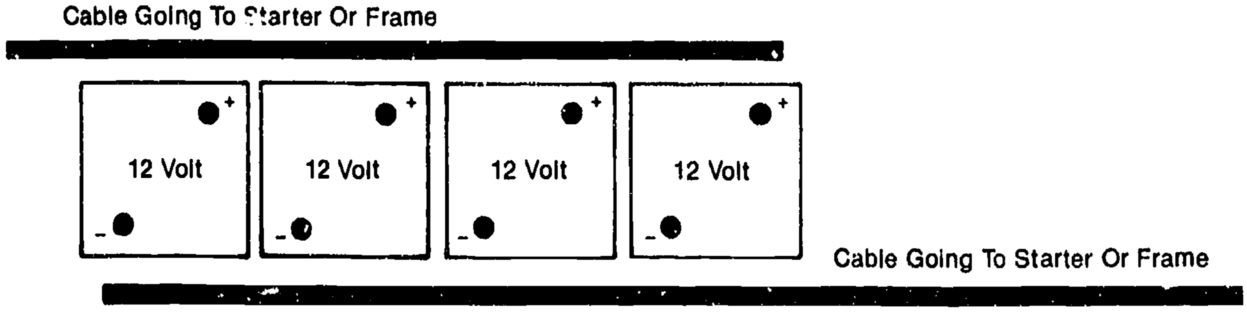
      2) 24-volt system



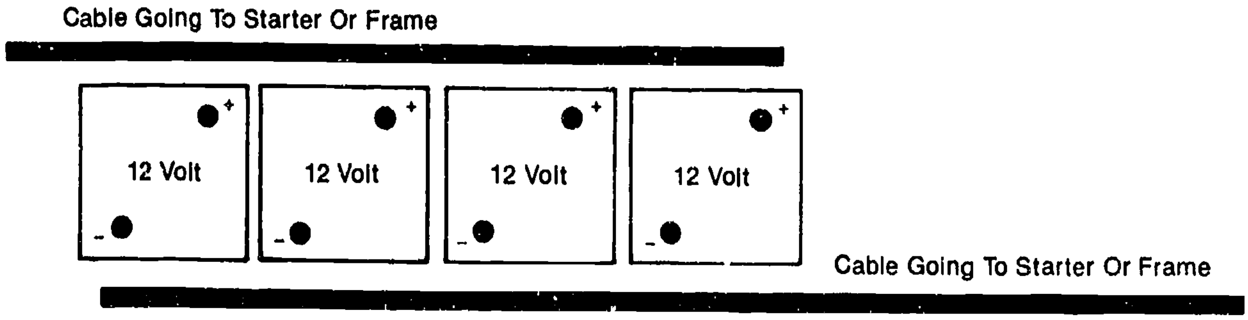
TEST

b. 12-volt batteries

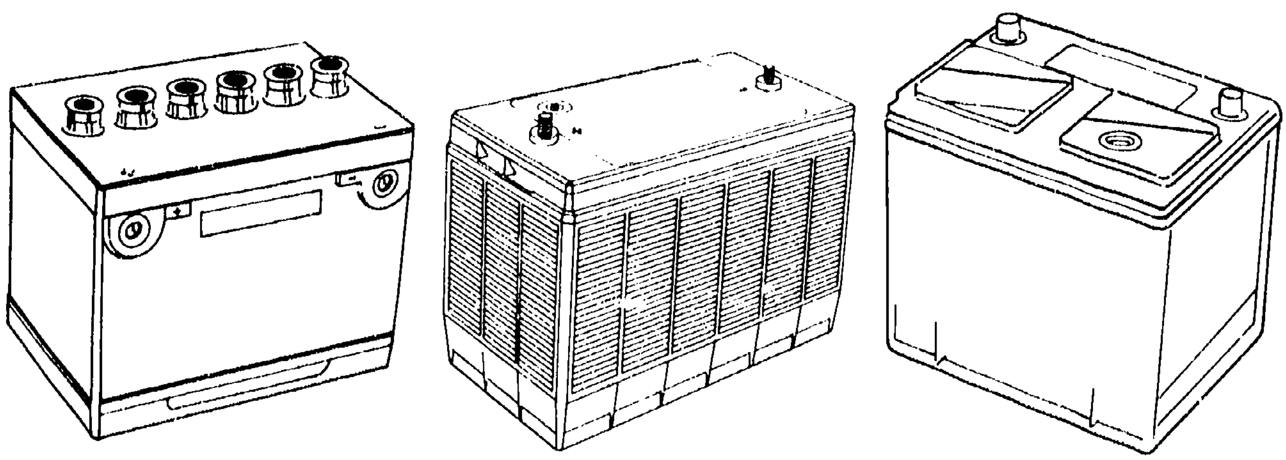
1) 12-volt system



2) 24-volt system



9. Identify the following types of battery terminal constructions.



a. ______________ b. ______________ c. ______________

TEST

10. Select from the following list safety rules to be observed during the care and maintenance of batteries by placing an "X" beside the appropriate rule(s).

_____a. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces.

_____b. Flames or sparks can cause gases given off by battery to explode.

_____c. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries.

_____d. Leave charger in the "on" position when connecting and disconnecting batteries.

_____e. Flush immediately with water any area of skin which acid has contacted.

_____f. Avoid breathing fumes from a battery that is being charged.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:

    a. Troubleshoot a battery. (Job Sheet #1)

    b. Remove, service, and replace battery. (Job Sheet #2)

    c. Measure specific gravity of a conventional battery. (Job Sheet #3)

    d. Load test a battery. (Job Sheet #4)

    e. Charge test a battery for three minutes. (Job Sheet #5)

STORAGE BATTERIES
UNIT IV

ANSWERS TO TEST

1. a. 1 e. 6
   b. 2 f. 4
   c. 5 g. 7
   d. 3

2. a. Supplies current for cranking the engine
   b. Supplies current when the demand exceeds the output of the charging systems.
   c. Stabilizies the voltage in the system during operation.

3. a. Conventional
   b. Maintenance free

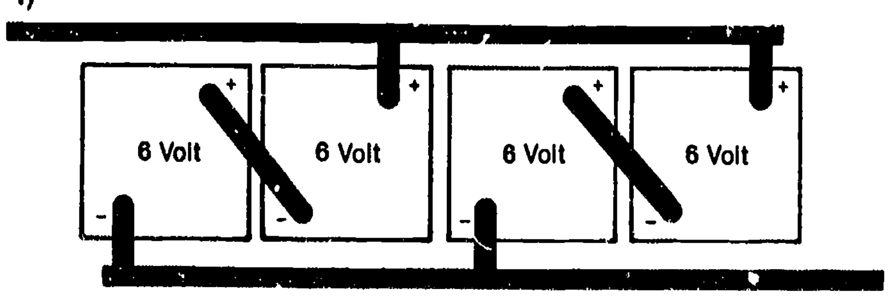
4. a. M e. M
   b. M f. C
   c. C g. M
   d. M h. M

5. a. 3
   b. 6

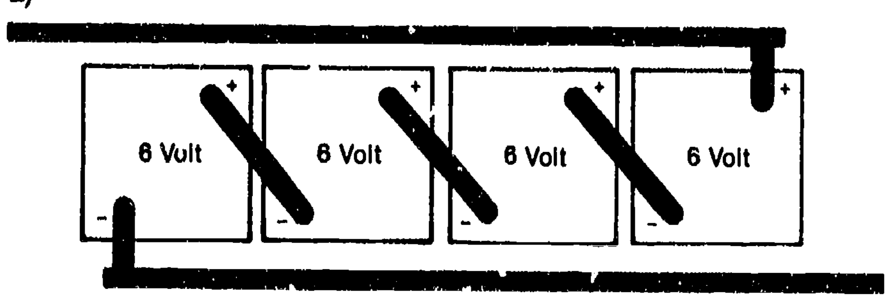
6. b

7. a. Fully
   b. Older
   c. Different
   d. Polarity

8. a. 1)

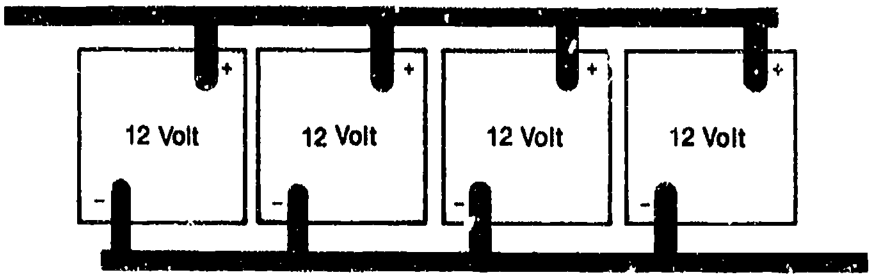


2)

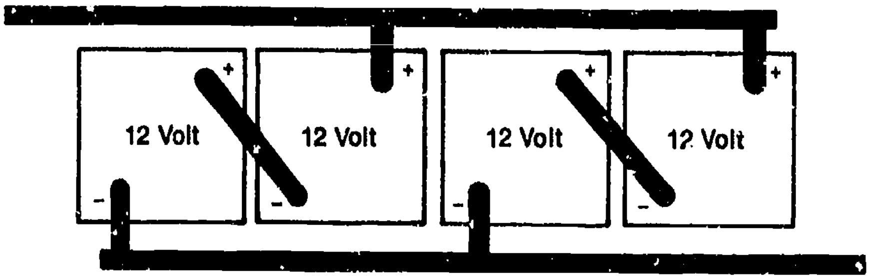


ANSWERS TO TEST

b. 1)



2)



9. a. Bolt-type side terminals
   b. Stainless steel stud terminals
   c. Battery post terminals

10. a, b, c, e, f

11. Performance skills evaluated to the satisfaction of the instructor

STARTING SYSTEMS AND CIRCUITS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to remove, replace, rebuild, and test a starter, and check voltage drop in a starter circuit. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to starting systems and circuits with their correct definitions.
2. List three types of starting systems.
3. List two sources of compressed air for air starting motors.
4. Select from a list components of a gasoline starting system.
5. Select from a list types of starting aids.
6. State the purpose of an electrical starting circuit.
7. Label the major parts in an electrical starting circuit.
8. Match parts of a starting circuit with the functions.
9. Select major parts of a starting motor.
10. Match component parts of a starting motor with their functions.

OBJECTIVE SHEET

11. Complete a statement concerning the conversion of electrical energy into mechanical energy.

12. Select true statements concerning how a starting motor is kept running.

13. Arrange in order the current flow in a starting motor circuit.

14. Identify types of starter field circuits.

15. Match types of starter field circuits with current flow.

16. List four types of starting motor switches.

17. Explain ways starter drives are engaged.

18. Identify types of electromagnetic or lever shift drives.

19. Arrange in order the steps in the operation of a series-parallel switch.

20. Arrange in order the steps in the operation of a transformer-rectifier unit.

21. Demonstrate the ability to:

    a. Remove and replace a starter. (Job Sheet #1)

    b. Disassemble, test, and reassemble a starter. (Job Sheet #2)

    c. Test a starter motor (no-load). (Job Sheet #3)

    d. Rebuild and test a starter solenoid. (Job Sheet #4)

    e. Check voltage drop in a starter circuit. (Job Sheet #5)

STARTING SYSTEMS AND CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate different designs of starters.
2. Take a field trip to a starter rebuilding shop.
3. Show film strip.
4. Have students bring in starters to rebuild.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Foutes, William. *Diesel Mechanics: Electrical Systems.* Stillwater, OK: Mid-America Vocational Curriculum Consortiu~, 1982.

B. *Master Crawler 850 Service Manual.* Racine, WI: J.I. Case Company,1975.

C. *Motor Heavy Truck Repair Manual.* 2nd ed. New York, NY: Hearst Books, 1985.

D. Schulz, Erich J. *Diesel Mechanics.* 2nd ed. Dallas: McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

Delco Remy Service Manual #1.2
AC-Delco
General Motors Building
Detroit, MI 48202

B. **Filmstrips**

1. *Luce-Neville Starting Motor*
   Order #A5047
   Educational Communications Inc.
   Dept. M
   761 Fifth Avenue
   King of Prussia, PA 19406

2. *The Automotive Starting System Explained*
   Order #B-435
   Teaching Aids Incorporated
   Post Office Box 1798
   Costa Mesa, CA 92628-0798

STARTING SYSTEMS AND CIRCUITS
UNIT V

INFORMATION SHEET

I. **Terms and definitions**

A. Armature — Main drive of starter motor; converts electrical energy into mechanical energy

B. Brushes — Sliding contacts to feed electrical energy from battery to commutator

C. Cemf — Counter electromotive force

D. Commutator — Metal segments attached to ends of wire loops to form contact surface on armature

E. Field winding — Wire wrapped around pole pieces to increase strength of magnetic field when current is passed through windings

F. Inertia — Tendency of a body in motion to remain in motion

G. Motor switch — Any switch that closes the circuit between the battery and starter motor

H. Pinion — Small gear that meshes with a larger gear

I. Pole pieces — Ends of a magnet in the field frame assembly of a starting motor

J. Solenoid — Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

K. Starter switch — Activates the motor switch

(NOTE: This switch may be either a key or push button.)

L. Voltage drop — The drop, or current used in cables

II. **Types of starting systems**

A. Electric motors

B. Gasoline engines

C. Air starters

INFORMATION SHEET

III. **Sources of compressed air for air starting motors** (Transparency 1)

A. Separate engine and compressor

B. Air brake compressor on highway diesel tractors

(NOTE: The air starting motor produces more torque to turn an engine over than an electric starter motor.)

IV. **Components of gasoline starting engine**

A. Gasoline engine

B. Clutch

C. Gear box

D. Drive pinion

V. **Types of starting aids**

(NOTE: Aids may be used singly or in combination.)

A. Glow plugs

B. Starting fluid

C. Block heater

D. Oil heater

VI. **Purpose of an electrical starting circuit** — Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine.

VII. **Major parts in an electrical starting circuit** (Transparency 2)

A. Battery

B. Starter switch

(NOTE The starter switch may be either a key or push button.)

C. Motor switch

(NOTE: The motor switch may be either magnetic or solenoid.)

D. Starting motor

INFORMATION SHEET

VIII. **Function of parts of an electrical starting circuit** (Transparency 2)

A. Battery — Supplies energy for the circuit

B. Starter switch — Activates the circuit

C. Motor switch — Closes circuit to motor and engages motor drive with fly-wheel

D. Starting motor — Drives flywheel to start engine

IX. **Major parts of a starting motor** (Transparency 3)

A. Motor switch

B. Field frame assembly

C. Armature

D. Drive mechanism

X. **Component parts and their functions** (Transparency 3)

A. Pole shoe — Forms a magnetic field of force around armature

B. Field winding — Wrapped around pole shoe to strengtnen magnetic field when current is passed through the winding

C. Armature — Converts electrical energy into mechanical energy to drive mechanism to crank engine

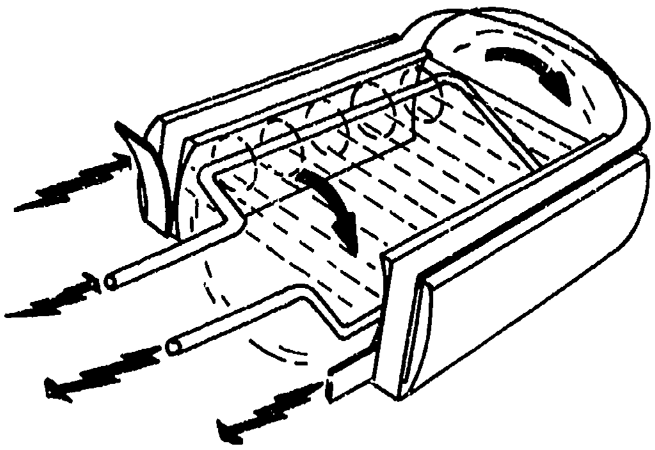
(NOTE: The magnetic field around the loop and the field between the pole shoes repel each other causing the loop or armature to turn.)

D. Commutator — Forms contact surface for battery to feed electrical current through armature

E. Brushes — Sliding contacts which feed electrical energy to the commutator

INFORMATION SHEET

XI. **Conversion of electrical energy into mechanical energy** — Current carrying conductor (armature) formed in a loop and mounted on a shaft; will cause the shaft to rotate when placed inside a magnetic field (field windings)



Loop of Wire Placed in Field Between Poles

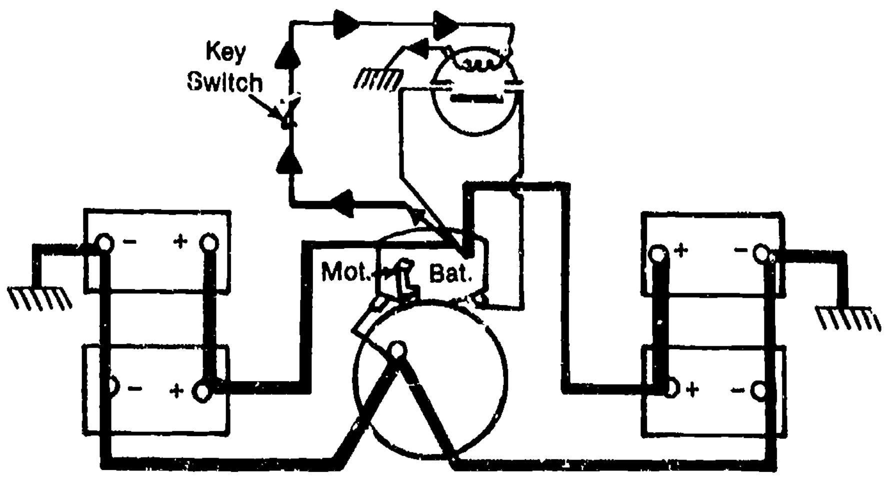
XII. **How a starting motor is kept running** (Transparency 4)

A. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

B. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (brushes) which causes the current to flow in the opposite direction in the armature windings.

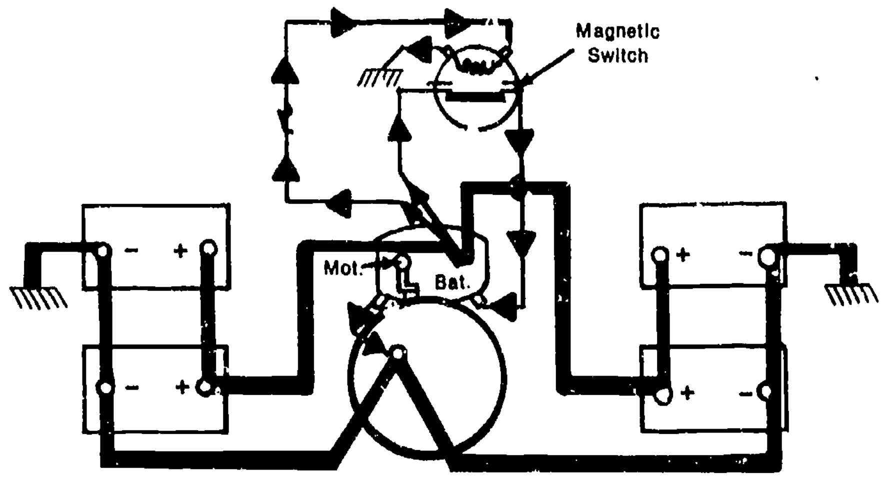
XIII. **Current flow in an electrical starting motor circuit**

A. With the key switch in the start position, current flows from the battery terminal of the starter through the magnetic switch and to ground.

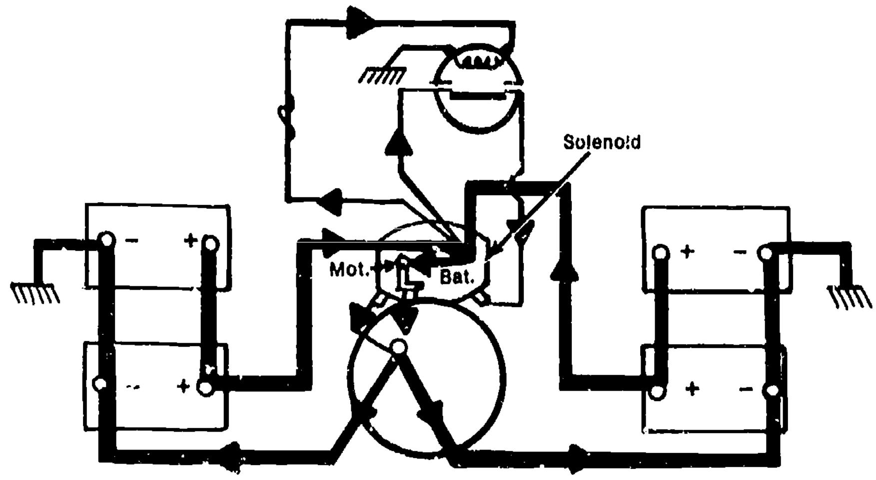


INFORMATION SHEET

B. The magnetic switch closes allowing current to flow from the battery terminal of the solenoid to the switch terminal of the solenoid.



C. The solenoid closes allowing current to flow from the battery terminal of the solenoid to the motor terminal of the solenoid and at the same time, engages the starter drive with the flywheel. Current then passes through the starter and back to ground.



XIV. **Types of starter field circuits** (Transparency 5)

A. Series-wound

B. Parallel-wound

C. Series-parallel-wound

D. Compound-wound

XV. **Types of starter field circuits and current flow** (Transparency 5)

A. Series-wound — Current flows through all the field windings before it flows through the two insulated brushes to the armature

INFORMATION SHEET

B. Parallel-wound — Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.

C. Series-parallel-wound — One third of the current flows through each pair of field windings to one of the three insulated brushes.

D. Compound-wound — One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.

(NOTE: The shunt coil is not affected by the counter voltage (CEMF) induced into the armature windings when passing through the magnetic field of the field coils.)

XVI. **Types of starting motor switches**

A. Manual

B. Solenoid

(NOTE: Solenoid provides a mechanical means for engaging the pinion with the flywheel.)

C. Magnetic

(NOTE: Magnetic switch does not provide mechanical shifting.)

D. Series-parallel

XVII. **Engaging starter drives**

A. Inertia of armature acting through drive mechanism

B. Electromagnetic plunger to mechanically shift pinion into mesh

XVIII. **Types of electromagnetic or lever shift drives** (Transparency 6)

A. Overrunning clutch

B. Sprag clutch drive

C. Positork® drive

XIX. **Operation of a series-parallel switch**

A. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.

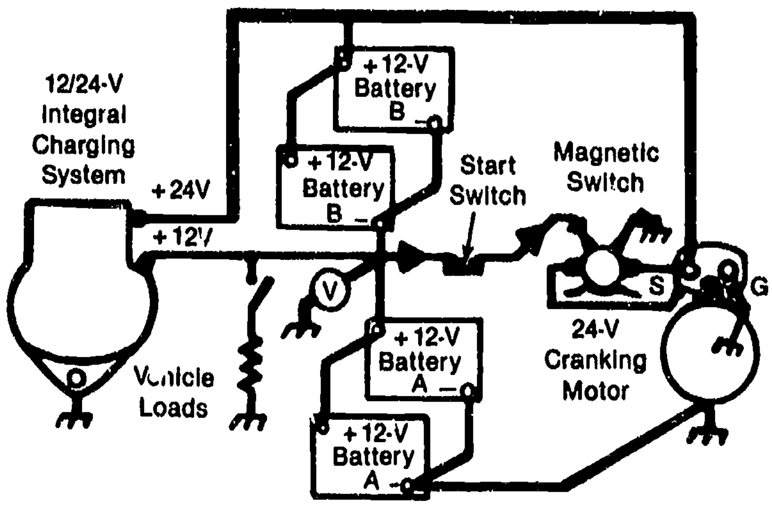
B. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over. (Transparency 7)

INFORMATION SHEET

C. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation. (Transparency 8)

XX. **Operation of a transformer-rectifier unit**

A. The operator closes the start switch, forcing 12 V from the batteries marked "A" through the magnetic switch, closing the cranking motor actuating circuit.



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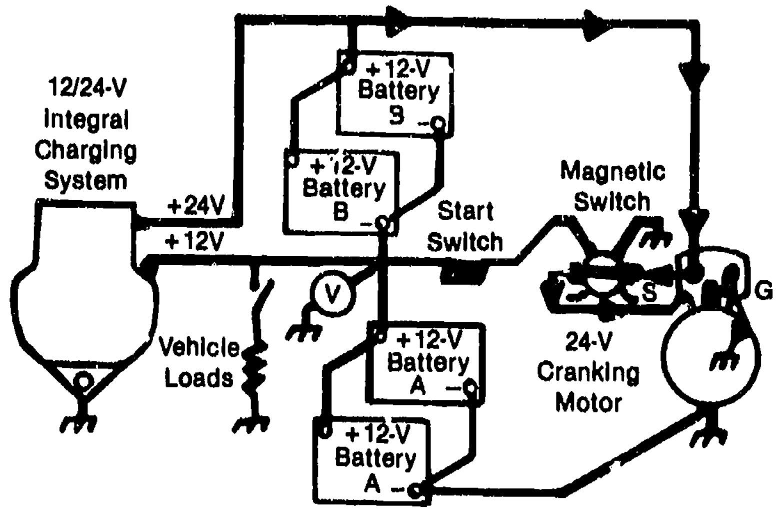
INFORMATION SHEET

B. The current for the solenoid switch and for cranking flows from the positive posts of the "B" batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.



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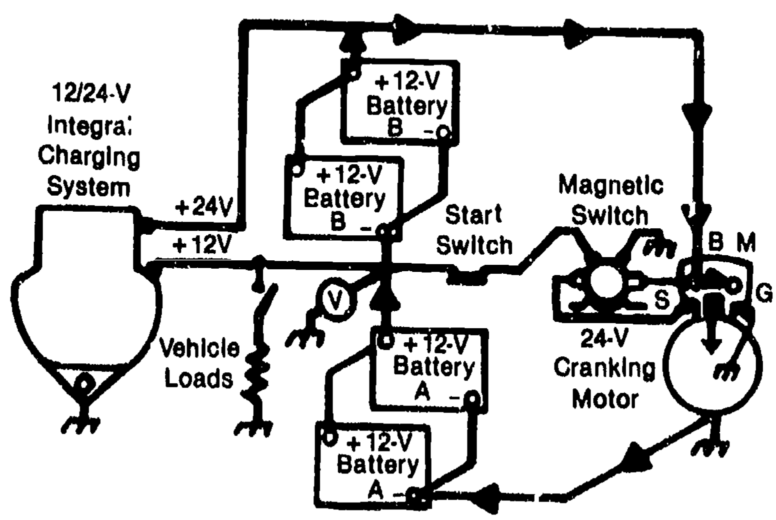
C. This action energizes the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative part of the batteries marked "A." This action connects both sets of batteries in series, creating 24 V for starting.



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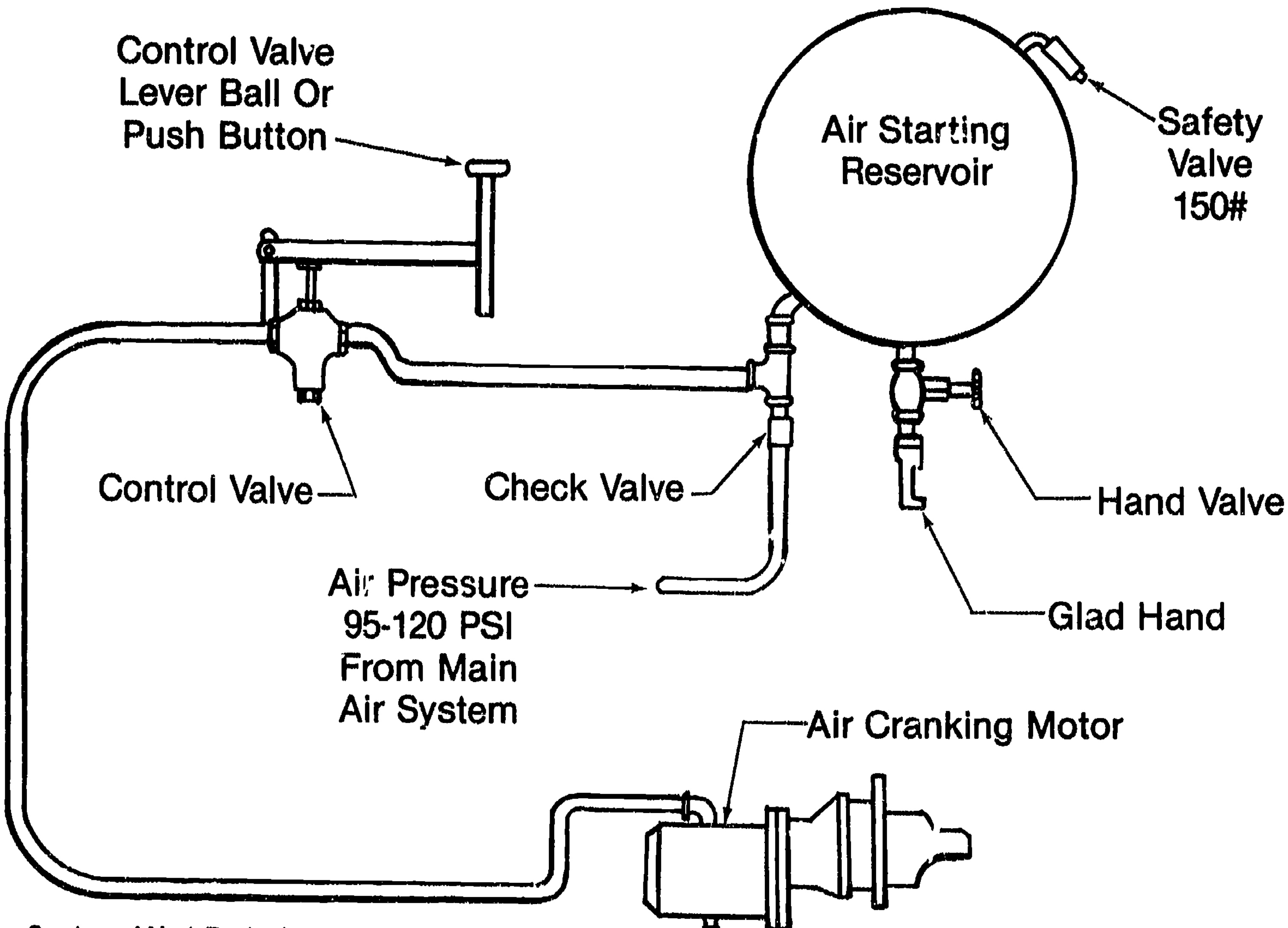
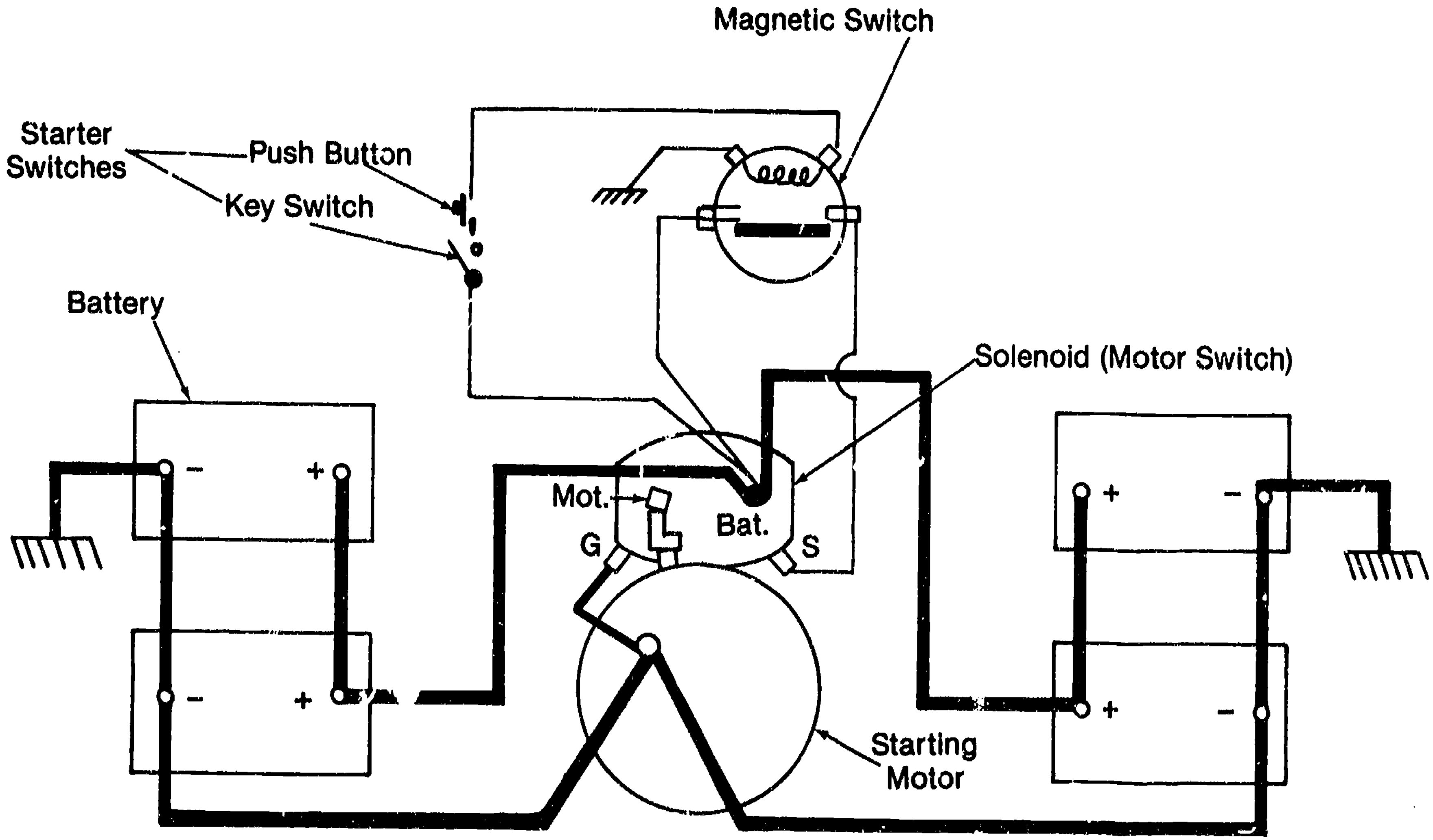
Air Starting System



Courtesy of Mack Trucks, Inc.

Parts in Starting Circuit



TM

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211

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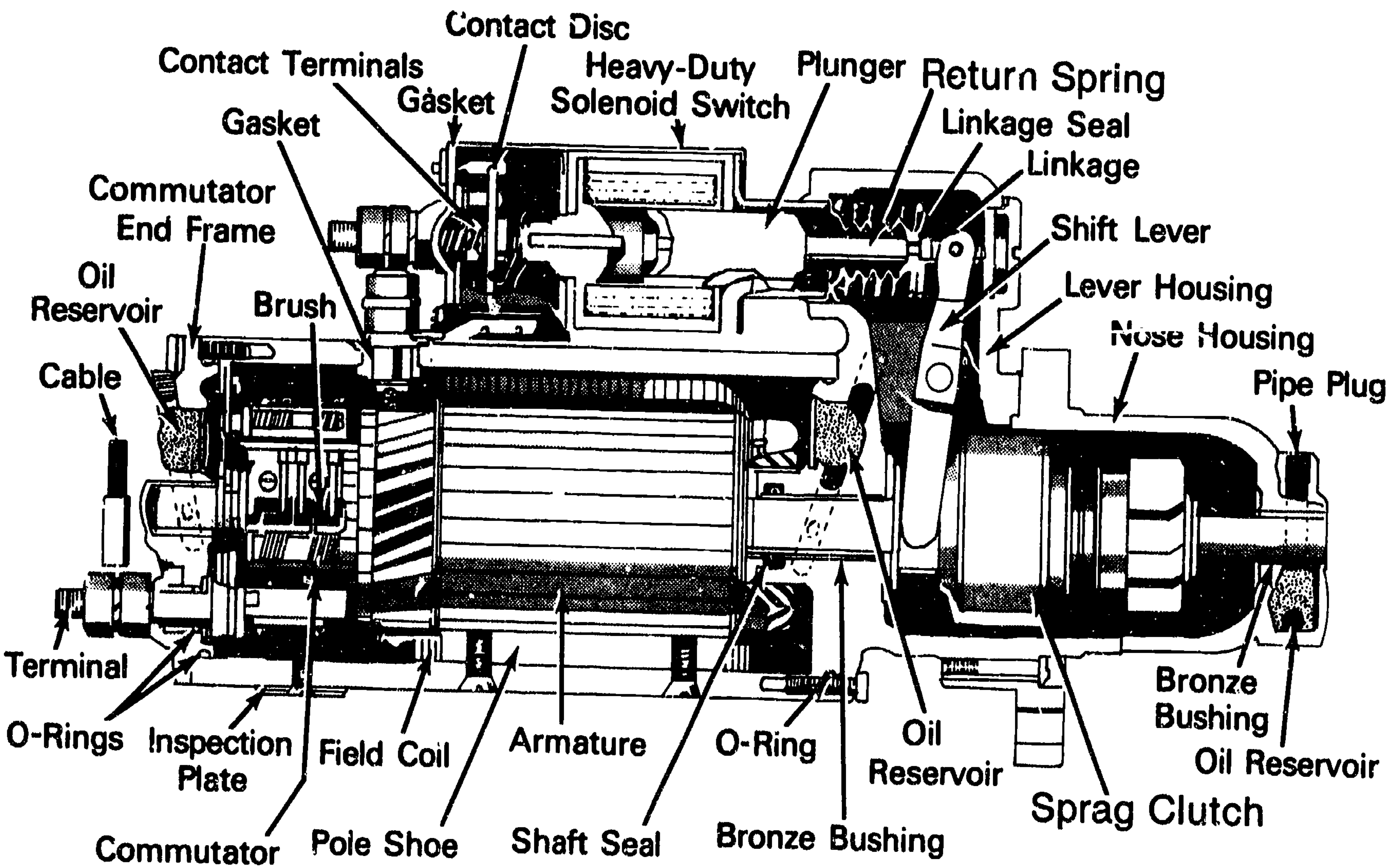
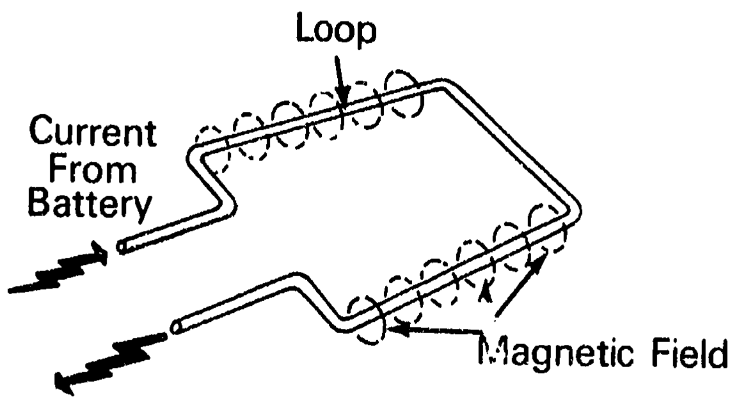
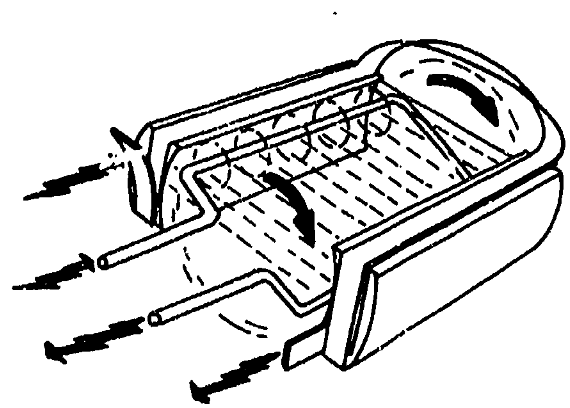
Parts of a Starting Motor



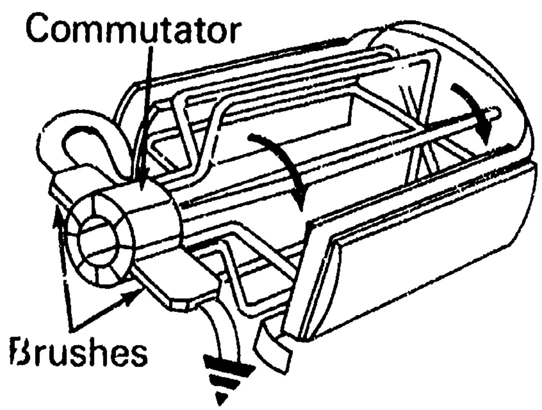
Components of Armature



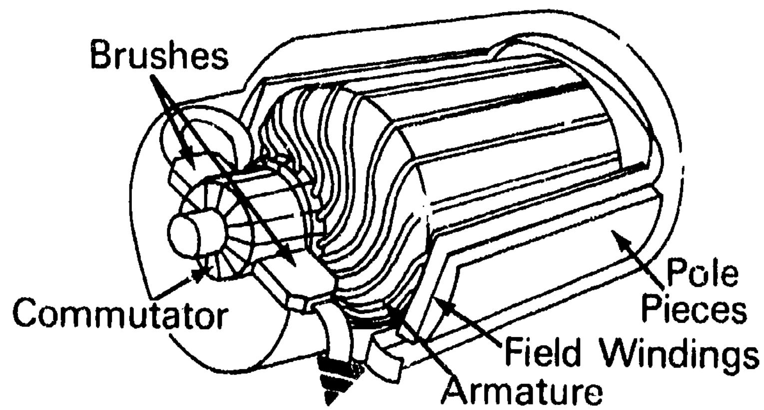
Loop Of "Live" Wire And Its Magnetic Field



Loop Placed In Field Windings

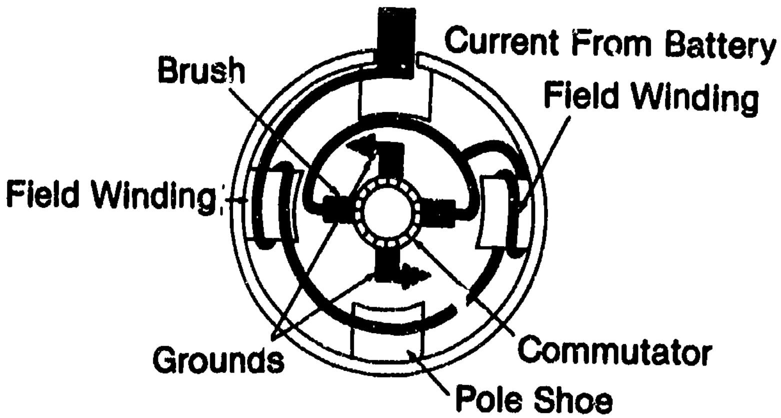


Armature For Starting Motor

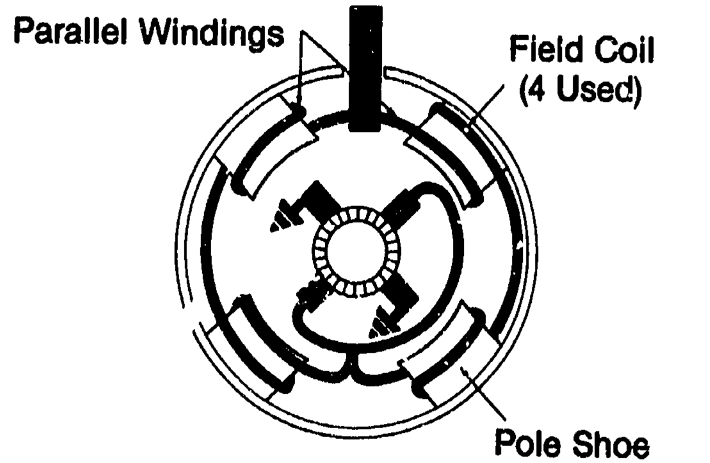


Armature And Brushes

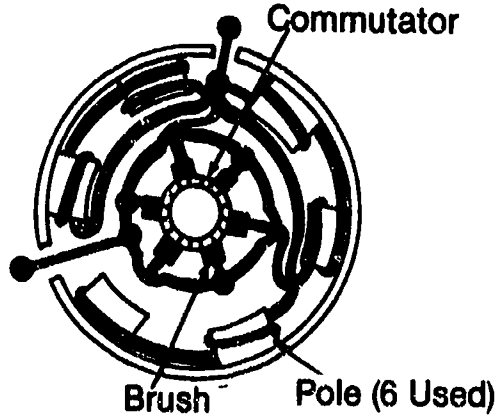
Starter Field Circuits



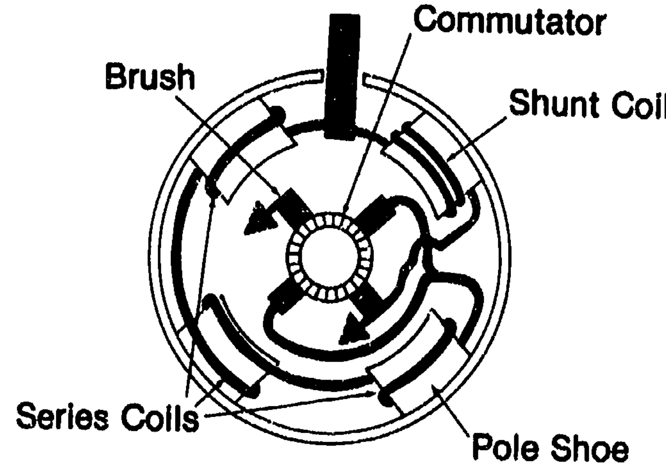
Four-Pole—Two-Coil Series-Wound Motor



Four-Pole—Four-Coil Parallel-Wound Motor

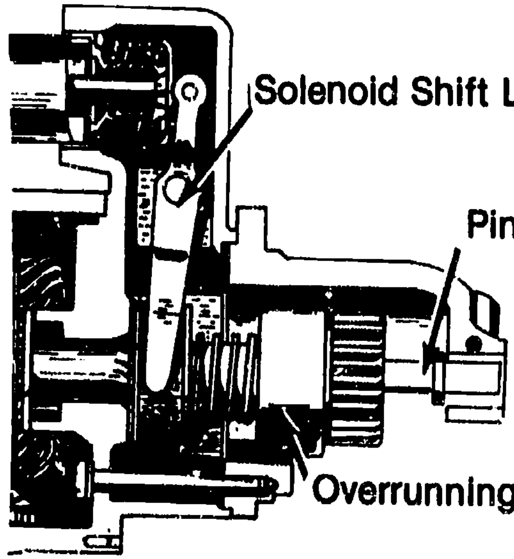


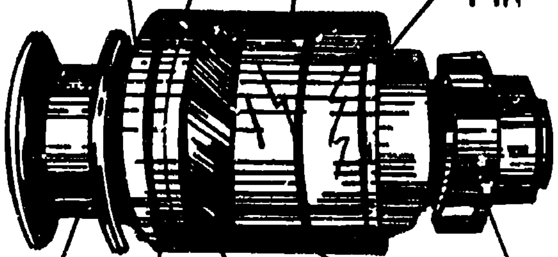
Six-Pole—Six-Coil Series-Parallel-Wound Motor



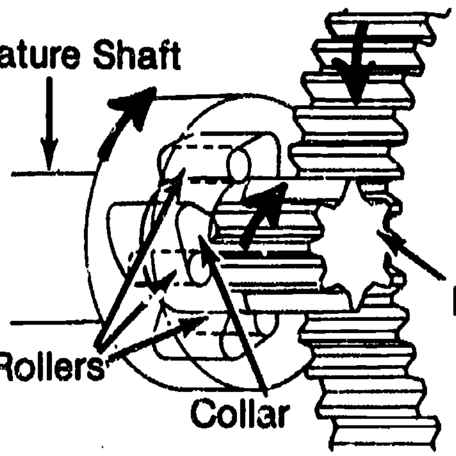
Compound-Wound Motor

Types of Electromagnetic or Lever Shift Drives

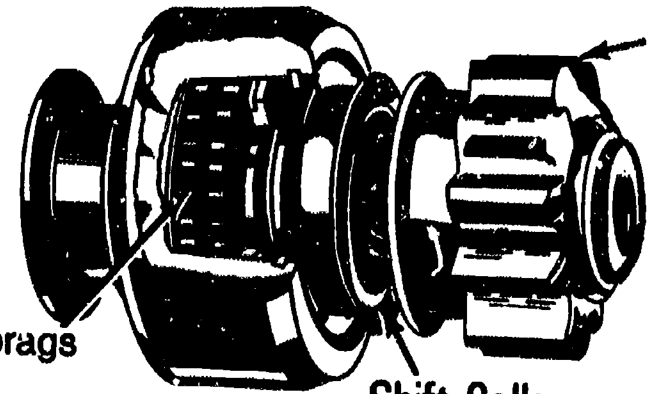




Positork Drive



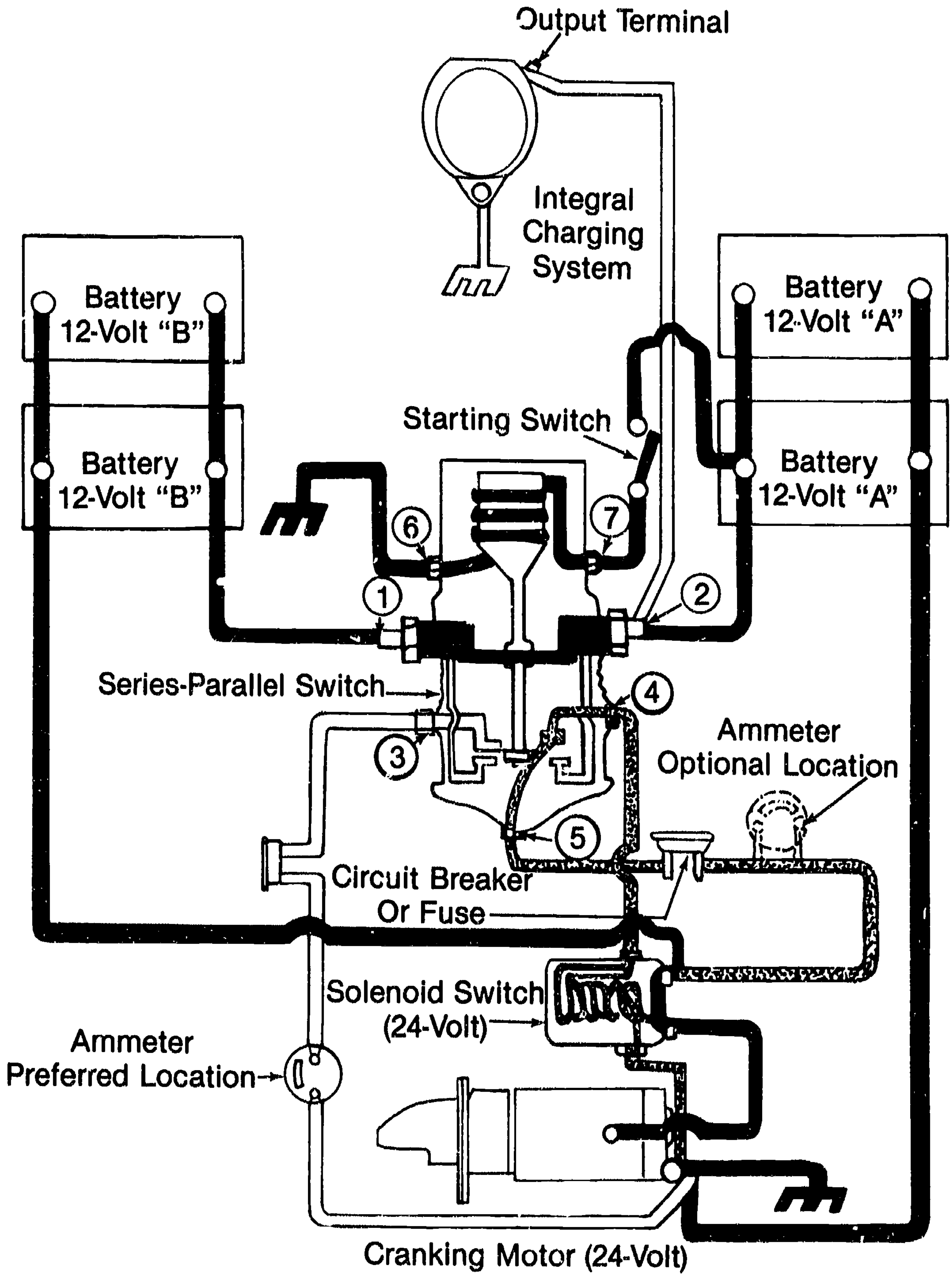
Overrunning Clutch Drive Engaged



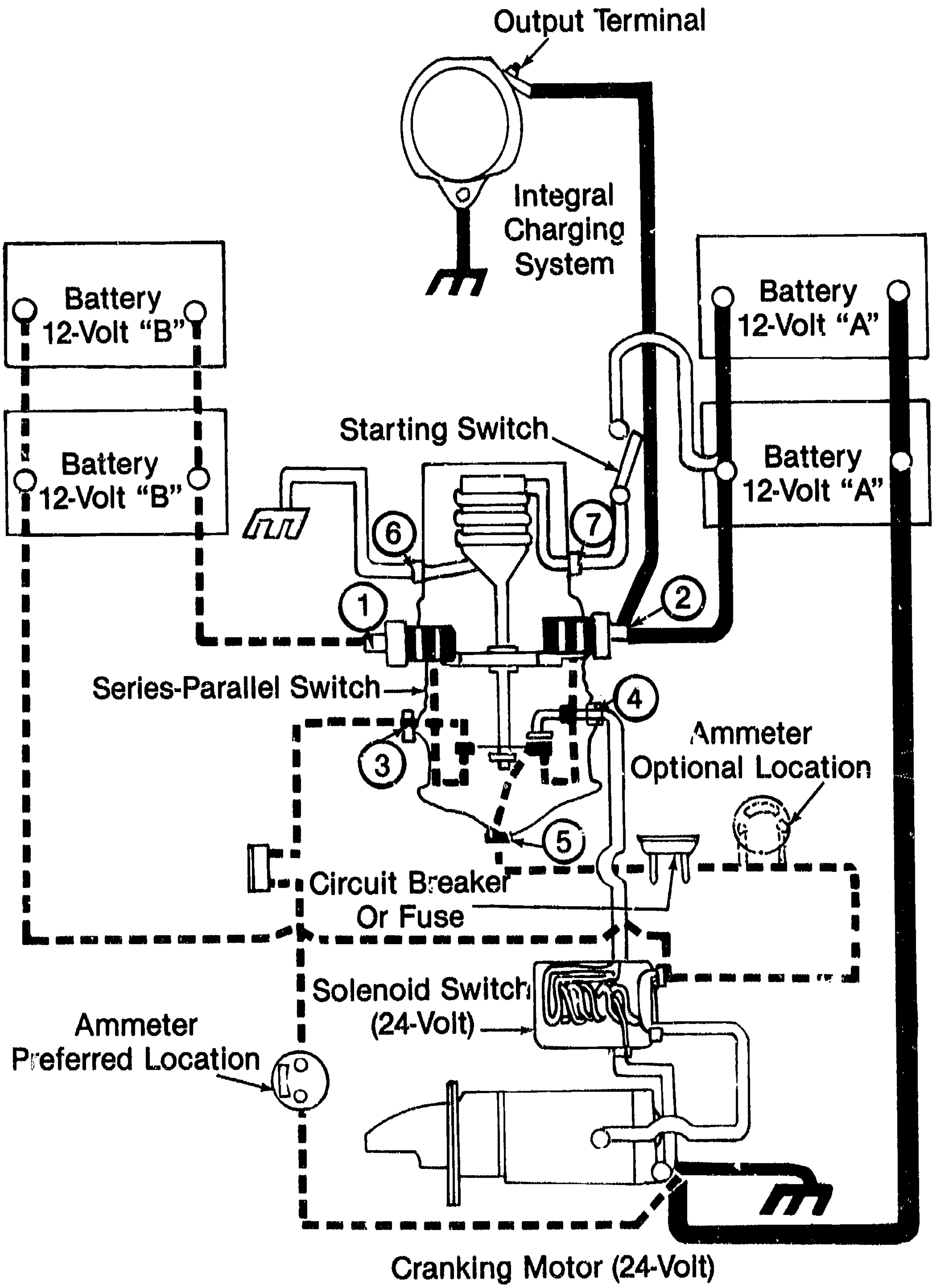
Sprag Clutch Drive

TM

Series-Parallel Switch — 24 Volts



Series-Parallel Switch — 12 Volts



STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #1 — REMOVE AND REPLACE A STARTER

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Battery cable pliers
4. Safety glasses
5. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

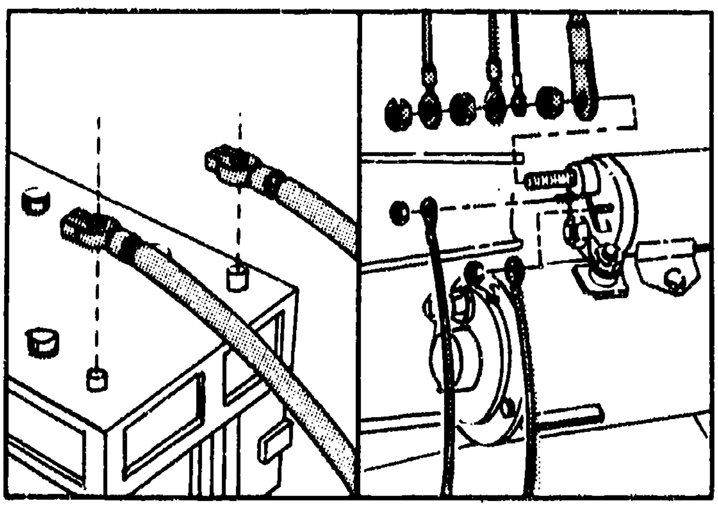
1. Remove starter.

   a. Disconnect battery ground cable.

   b. Remove the cables and electrical wires from the starter and label. (Figure 1)

   (NOTE: In some cases it may be necessary to remove the starter retaining bolts and allow the starter to be lowered to provide easy removal of the starter wires and cables.)

FIGURE 1



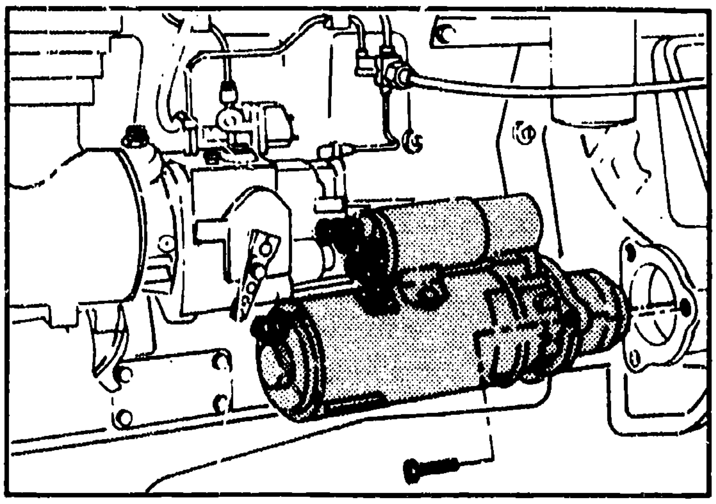
Courtesy of Cummins Engine Co., Inc.

JOB SHEET #1

c. Remove starter retaining bolts as required. (Figure 2)

(CAUTION: The starting motor mounting capscrews can be metric or standard thread sizes. Be sure to install the same size capscrews which were removed.)

FIGURE 2



Courtesy of Cummins Engine Co., Inc.

d. Remove other starter brackets if used.

e. Remove starter from engine.

(CAUTION: Starter motors are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.)

2. Replace starter

   a. Clean starter and block mounting surfaces.

   b. Position starter in mounting position and start retaining bolts.

   c. Tighten starter retaining bolts securely.

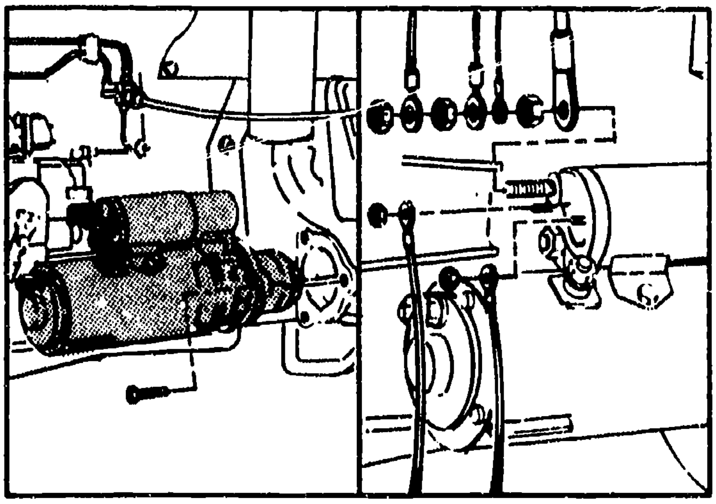
   d. Position starter wires and cables in place and start retaining nuts.

JOB SHEET #1

e. Tighten starter wires and retaining nuts securely. (Figure 3)

(NOTE: Avoid overtightening and twisting off small retaining nuts.)

FIGURE 3



Courtesy of Cummins Engine Co., Inc.

f. Replace any brackets that may have been removed and tighten securely.

g. Check all connections.

h. Replace battery ground cable.

i. Start engine two or three times to check starter action.

STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #2 — DISASSEMBLE, TEST, AND REASSEMBLE A STARTER

A. Tools and materials

1. Starter
2. Basic hand tool set
3. Suitable armature growler with test light
4. Two V blocks
5. Dial indicator
6. Safety glasses

B. Procedure

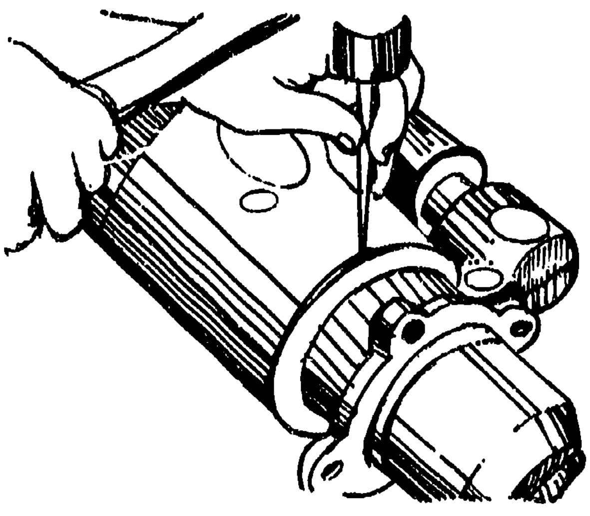
(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Disassemble starter.

   a. Clean starter before disassembly.

   b. Mark the commutator end frame, drive housing, and the field-frame assembly with a center punch. (Figure 1)

FIGURE 1



Courtesy of John Wiley & Sons, Inc. *Diesel Engine Repair* by John F. Dagel, © 1982.

(NOTE: These alignment marks will ensure proper commutator, end frame, drive housing, and field frame positions when reassembling.)

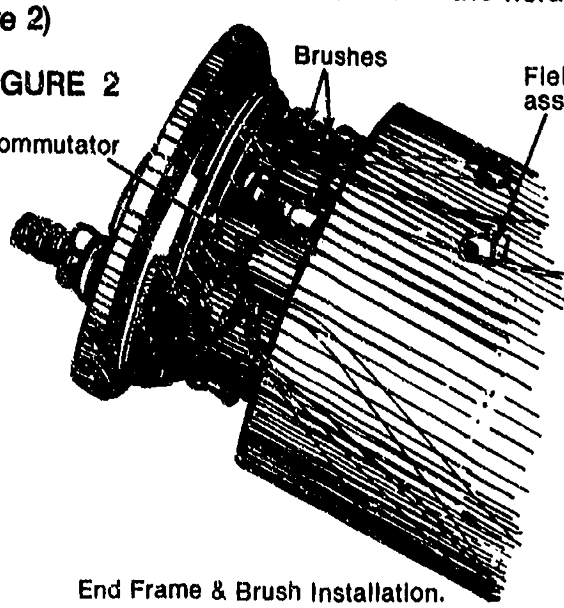
JOB SHEET #2

c. Remove the bolts that hold the commutator end frame and the field frame together.

(NOTE: Depending on which type starter you have, the bolts may be threaded into the main field frame or may be through bolts that reach through the field frame housing and thread into the shift lever housing.)

d. Remove the dust cover, if applicable, or brush inspection plugs and then remove the screws which connect the field coils to the brush holders. (Figure 2)

FIGURE 2



End Frame & Brush Installation. Delco-Remy enclosed shift starter

e. Remove the bolts that hold the lever and drive housing to the main field frame.

f. Remove starter end frame.

g. Grasp starter housing and remove the armature and drive assembly from the housing.

h. Remove the armature and drive assembly from the drive housing.

(NOTE: Sometimes the solenoid and shift lever assembly must be removed before the drive assembly and armature can be removed.)

i. Remove starter drive from armature shaft as follows:

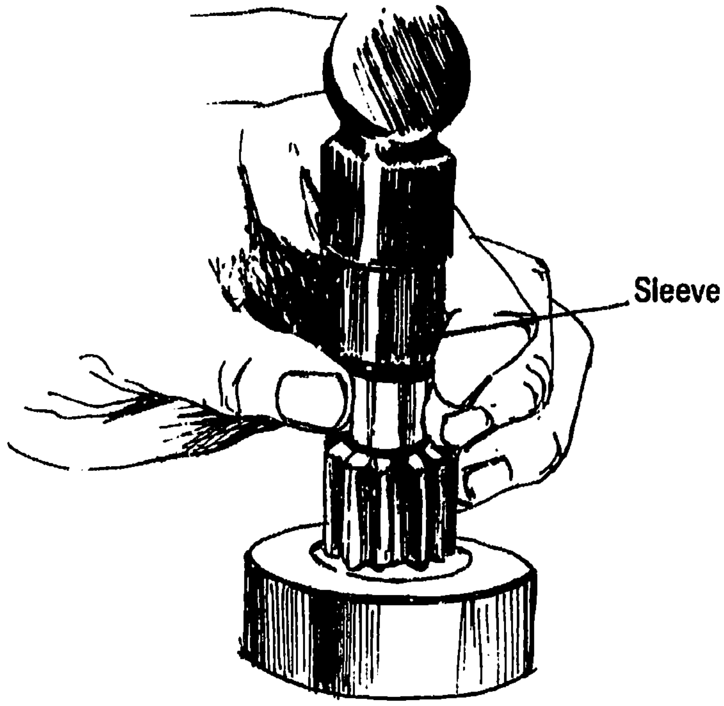
(NOTE: On motors using snap ring and retainer as a pinion stop, continue to Steps 1, 2, and 3.)

1) Remove thrust washer.

JOB SHEET #2

2) Tap retainer toward armature to free the snap ring. (Figure 3)

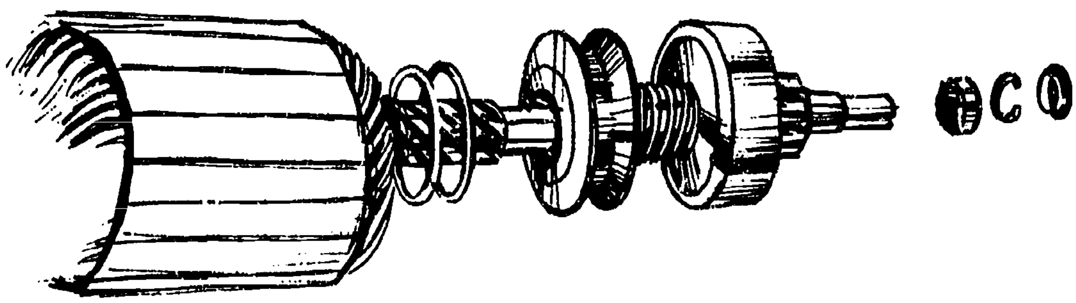
FIGURE 3



3) Remove snap ring and retainer.

4) Remove starter drive and assist spring. (Figure 4)

FIGURE 4



j. Remove starter brushes, if required.

2. Test and service starter.

a. Clean all starter components.

(NOTE: Clean all parts by wiping with clean cloth. The armature, field coils, and starter drive assembly must not be washed in solvent.)

b. Arrange all starter components for inspection.

c. Inspect starter bushing for looseness and replace as required.

JOB SHEET #2

d. Inspect starter brushes for wear.

(NOTE: Brushes worn to half their original length or less should be replaced.)

e. Inspect the starter drive.

(NOTE: The starter drive pinion gear should turn freely in one direction and lock when turned slowly in the other direction.)

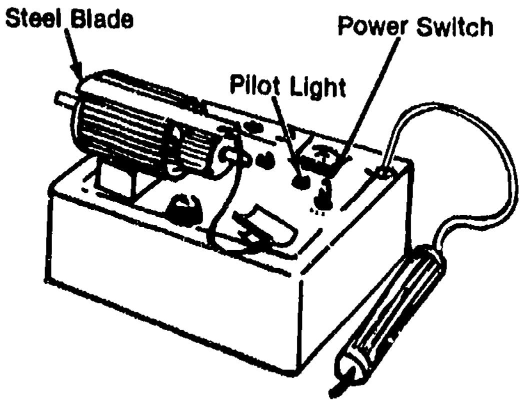
f. Inspect armature commutator.

(NOTE: If the armature commutator is rough or out-of-round, it should be turned down using suitable equipment.)

g. Test the armature for short circuits. (Figure 5)

(NOTE: Place the armature on a growler and rotate the armature while holding a hacksaw blade over the armature core. If the blade vibrates, the armature is shorted and will require replacement.)

FIGURE 5



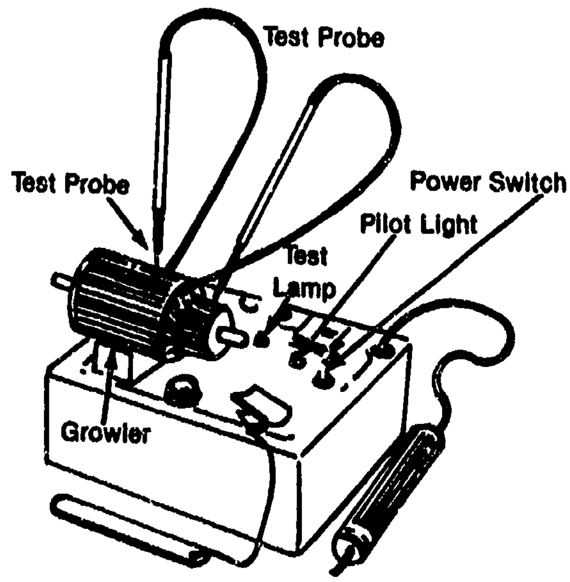
Courtesy of J.I. Case Company.

JOB SHEET #2

h. Check armature for ground. (Figure 6)

(NOTE: Place one lead of a test lamp on the armature core or shaft and the other on the commutator. If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 6



Courtesy of J.I. Case Company.

i. Check armature shaft runout.

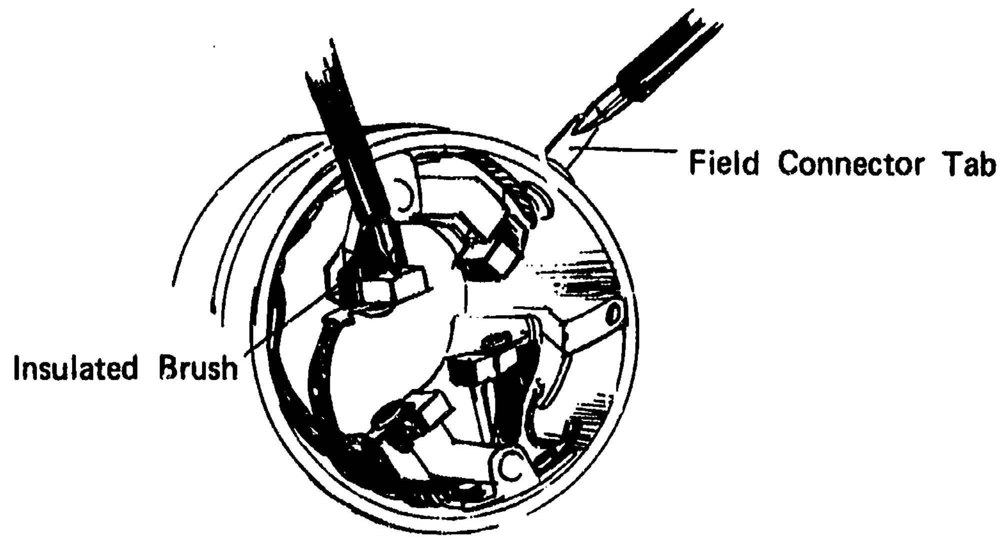
(NOTE: Place the armature between two V blocks and position a dial indicator on the armature-shaft center-bearing surface. Rotate the armature 360° to note the runout. If it is higher than .003 of an inch, the shaft must be straightened.)

JOB SHEET #2

j. Check field coil for open circuit. (Figure 7)

(NOTE: Place one lead of the test lamp on the insulated brush and the other on the field connection tab. If the lamp does not light, the field coils are open and will require replacement.)

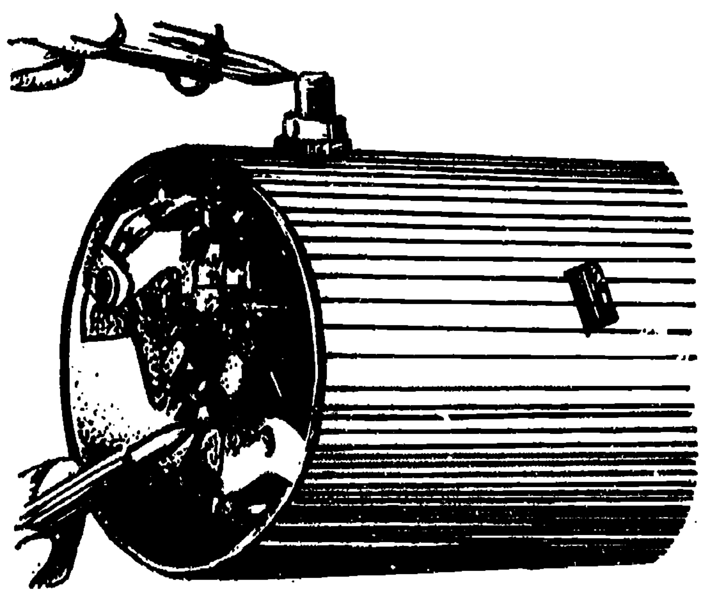
FIGURE 7



k. Check field coil for ground. (Figure 8)

(NOTE: Place one lead of the test lamp on the field connector tab and the other on the grounded brush. If the lamp lights, the field coils are grounded and will require replacement.)

FIGURE 8



l. Test, inspect, and replace any parts that are worn or damaged before reassembling starter.

JOB SHEET #2

3. Reassemble starter.

   a. Reassemble solenoid in reverse order of disassembly.

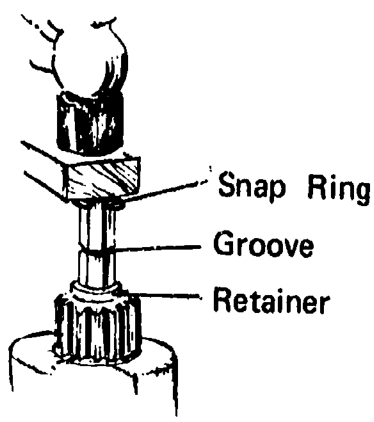
   b. Lubricate all bushings, wicks and oil reservoirs with SAE #20 oil.

   c. On motors using snap ring and retainers, reassemble in the following manner.

      1) Install starter drive on armature shaft.

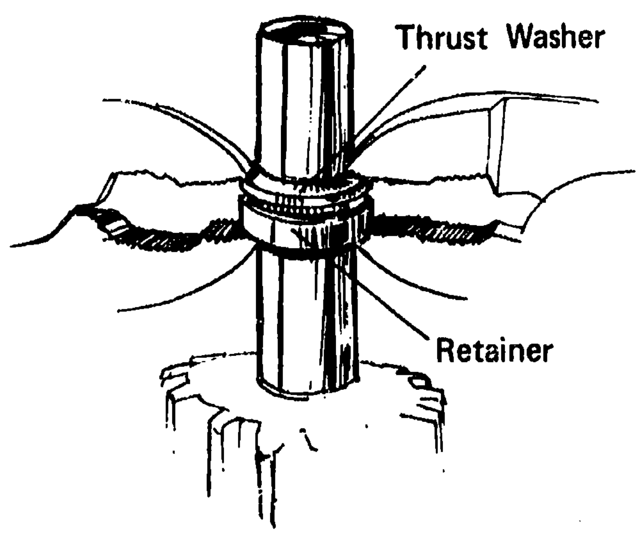
      2) Drive snap ring on shaft. (Figure 9)

FIGURE 9



      3) Force snap ring into retainer. (Figure 10)

FIGURE 10



      4) Lubricate drive housing bushing with 4 to 5 drops of S.A.E. #20 oil.

      5) Make sure thrust collar is in place against snap ring and retainer.

JOB SHEET #2

d. Check pinion clearance.

(NOTE: Shift starter drive into the cranking position and check clearance between starter drive and drive stop. Check with specifications and repair or adjust when needed.)

e. Test starter with a battery and jumper cables to determine starter motor performance.

STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #3 — TEST A STARTER MOTOR (NO-LOAD)

A. Tools and materials

1. Starter
2. Basic hand tool set
3. Fully charged battery
4. Ammeter
5. Starter technical manual specifications
6. Voltmeter
7. Carbonpile resistor
8. Tachometer
9. Safety glasses
10. Appropriate service manual

B. Procedures

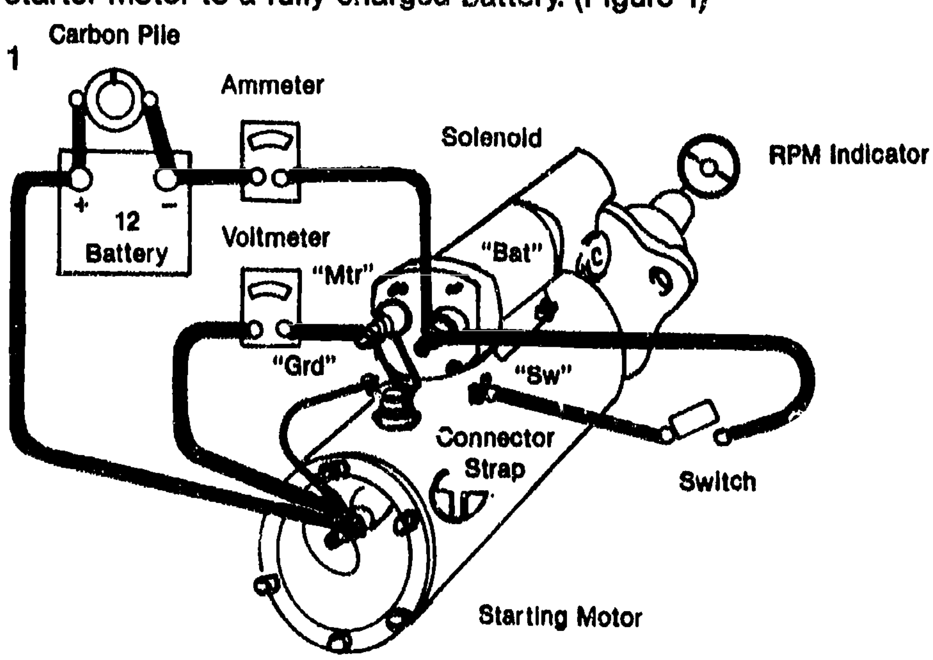
(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Conduct no-load test.

   a. Remove starter from engine.

   b. Connect starter motor to a fully charged battery. (Figure 1)

FIGURE 1



Reprinted from *MOTOR Heavy Truck Repair Manual*

JOB SHEET #3

c. Connect an ammeter between battery and battery terminal of solenoid. (Figure 1)

d. Connect a switch with leads from battery terminal of solenoid to the switch ("SW") terminal of the solenoid. (Figure 1)

e. Connect voltmeter to the motor terminal of solenoid and to ground terminal of starter. (Figure 1)

f. Connect carbon pile resistor across the battery. (Figure 1)

g. Place a tachometer on end of armature to measure armature speed. (Figure 1)

h. Start motor by connecting leads to battery terminal.

i. Vary the carbon pile resistor until the specified voltage is shown on the voltmeter.

j. Read the ammeter for the current draw.

k. Read the tachometer for the armature speed.

l. Compare the readings with the technical manual specifications for the starter motor being tested.

2. Interpret no-load test results by checking the problems you find.

_____a. Rated current draw and no-load speed indicates a normal starter motor condition.

_____b. Low free speed and high current draw indicate:

_____1) Too much friction

_____2) Shorted armature

_____3) Grounded, armature of fields

_____c. Failure to operate with high current draw indicates:

_____1) A direct ground in the terminal or fields

_____2) Frozen bearings

_____d. Failure to operate with no current draw indicates:

_____1) Open field circuit

_____2) Open armature coils

_____3) Broken brush springs, worn brushes, or high insulation between commutator bars

JOB SHEET #3

_____e. Low speed and low current draw indicates high internal resistance due to poor connections, dirty commutator, or an open field circuit.

_____f. High free speed and high current draw indicate shorted fields.

Obtain instructor's initials here __________ before proceeding to Job Sheet #4.

(NOTE: Any of these problems indicate a need to rebuild the starter as outlined in Job Sheet #4.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #4 — REBUILD AND TEST A STARTER SOLENOID

A. Tools and materials

1. Solenoid
2. Basic hand tool set
3. Voltmeter
4. Carbonpile resistor
5. Ammeter
6. Safety glasses

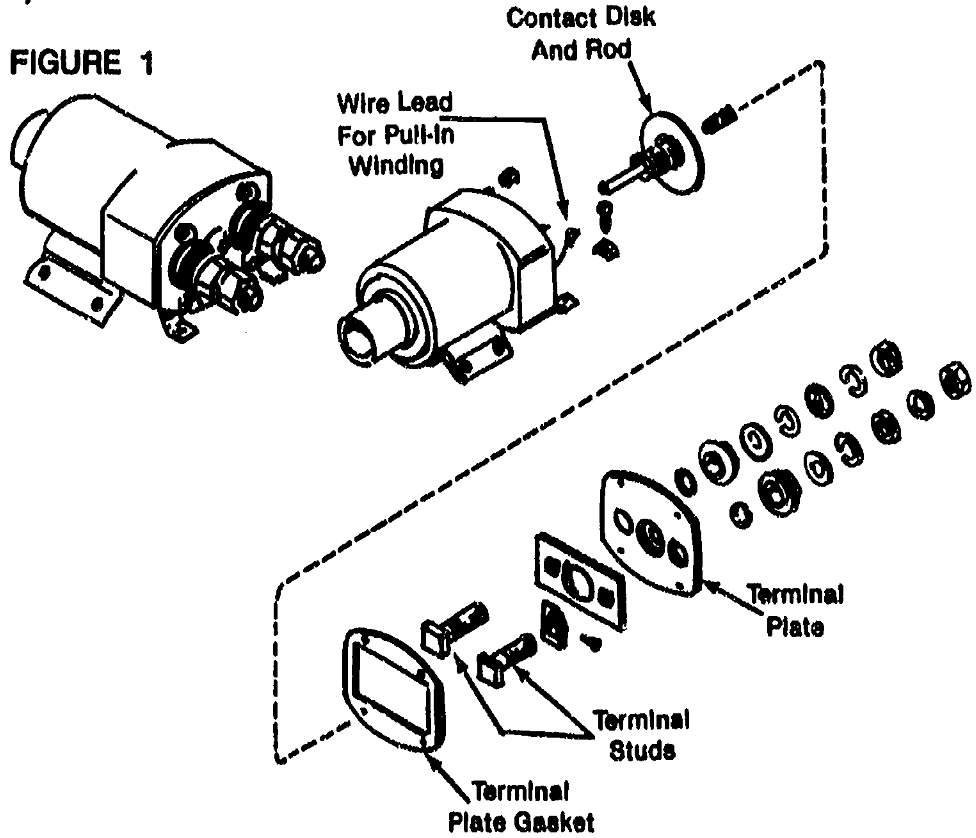
B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Disassemble and assemble solenoid.

   a. Remove the screws or nut attaching the terminal plate assembly. (Figure 1)

FIGURE 1



Starter Solenoid, Exploded View

Courtesy of J.I. Case Company.

JOB SHEET #4

b. Remove the screw that connects the pull in winding wire to the motor terminal. (Figure 1)

c. Remove contact disk and rod. (Figure 1)

d. Remove nuts on terminal studs and remove studs.

e. Clean and inspect all components.

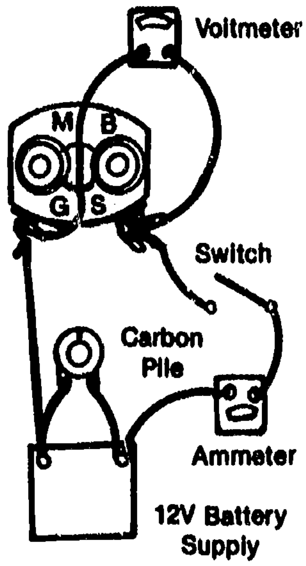
f. Replace or repair all pitted or worn parts.

g. Reassemble solenoid in reverse order of disassembly.

2. Check solenoid hold-in windings.

a. Make the test connections as shown in Figure 2.

FIGURE 2



Hold-In Winding Test
Courtesy of J.I. Case Company.

b. Close the switch and adjust the carbon pile to decrease the battery voltage to the specified voltage. (Figure 2)

c. Record ammeter reading, turn carbon pile off and open the switch.

d. Compare ammeter reading with the test specifications.

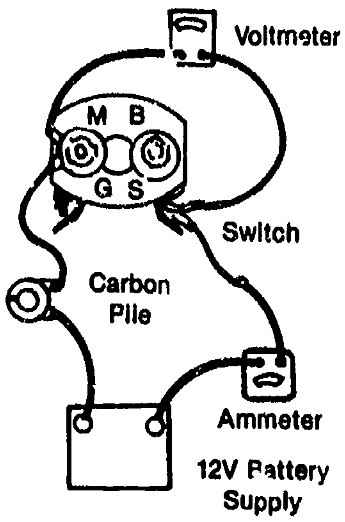
(NOTE: A high reading indicates a shorted winding. A low reading indicates excessive resistance.)

JOB SHEET #4

3. Check pull-in winding.

   a. Make test connections as shown in Figure 3.

FIGURE 3



Pull-In Winding Test

Courtesy of J.I. Case Company.

   b. Close the switch and adjust the carbon pile to decrease the battery voltage to the specified voltage.

      (CAUTION: To prevent overheating, do not energize the pull-in winding more than 15 seconds.)

   c. Record the ammeter reading, turn the carbon pile off and open the switch.

   d. Compare ammeter reading with the test specification.

      (NOTE: A high reading indicates a shorted winding. A low reading indicates excessive resistance.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

JOB SHEET #5 — CHECK VOLTAGE DROP IN A STARTER CIRCUIT

A. Tools and materials

1. Engine
2. Voltmeter
3. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system, and follow all shop safety procedures.)

1. Check insulated cables.

   (NOTE: The following procedures are for a 12 volt negative ground system, using a 40 M.T. starter.)

   a. Connect voltmeter positive lead to positive battery terminal. (Figure 1)

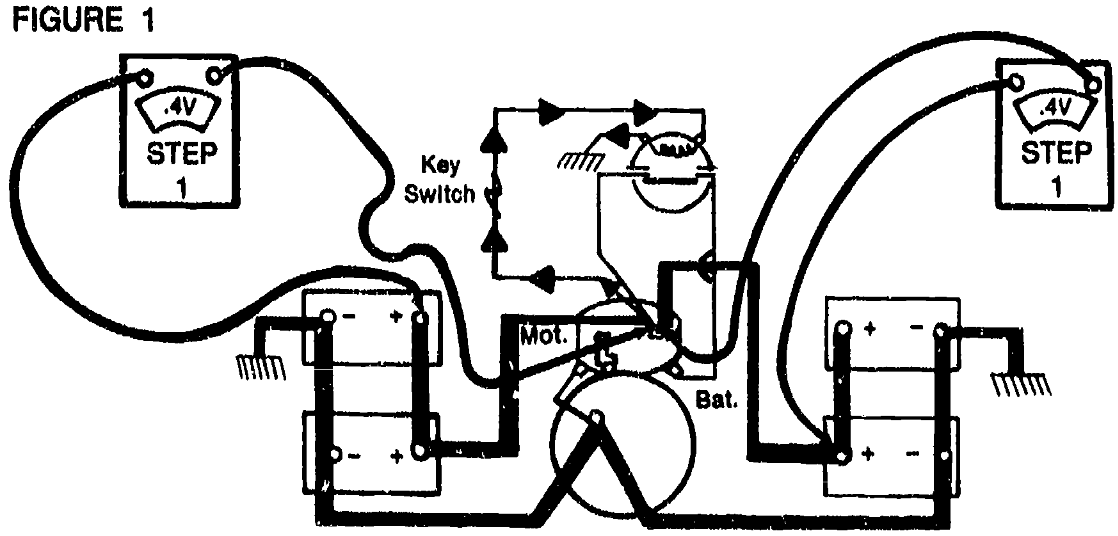
   b. Connect negative voltmeter lead to the battery terminal of the solenoid. (Figure 1)

   c. Set voltmeter on lowest scale.

   d. Prevent engine from starting.

   e. Crank engine and read meter.

FIGURE 1



(CAUTION: A cranking motor must never be used for more than 30 seconds at any time and cranking should not be repeated without a pause of two minutes.)

JOB SHEET #5

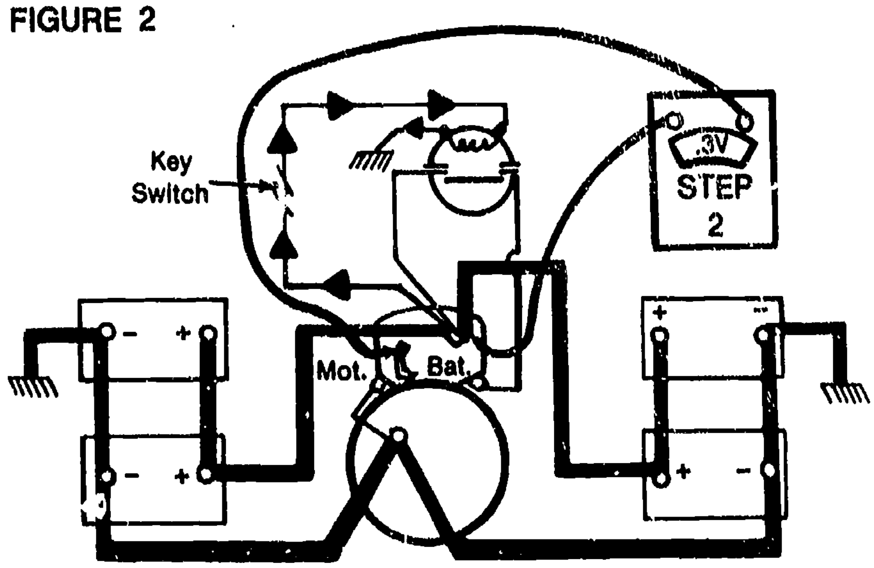
f. Check voltage drop.

(NOTE: If the voltage drop exceeds 0.4 volts, excessive resistance is indicated.)

2. Check solenoid contacts.

a. Connect positive voltmeter lead to the battery terminal of solenoid. (Figure 2)

FIGURE 2



b. Connect negative voltmeter lead to the motor terminal of solenoid. (Figure 2)

c. Crank engine and read meter.

d. Check voltage drop.

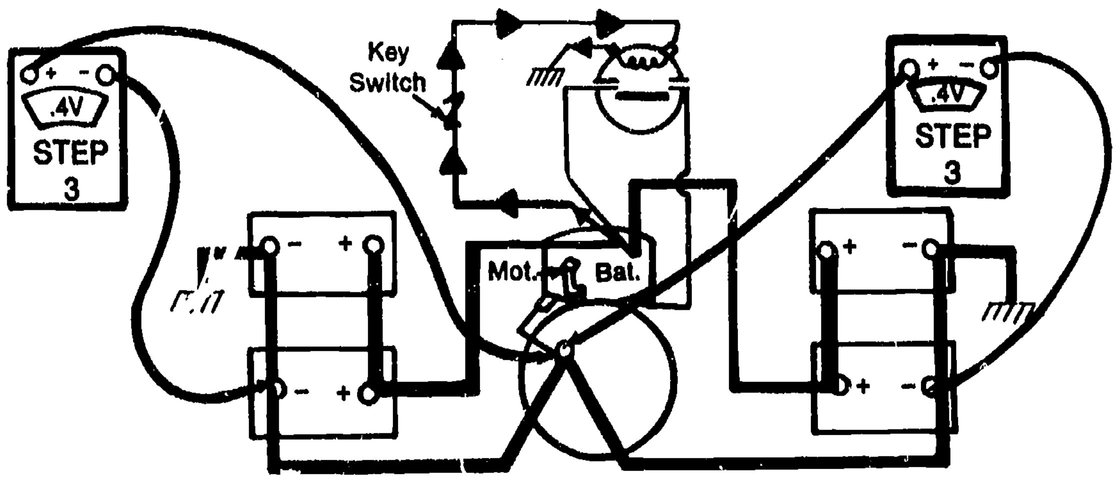
(NOTE: If voltage drop exceeds 0.3 volts, excessive resistance is indicated.)

JOB SHEET #5

3. Check ground cable.

   a. Connect voltmeter positive lead to the ground terminal of starter. (Figure 3)

   FIGURE 3



   b. Connect voltmeter negative lead to the negative post of battery. (Figure 3)

   c. Crank engine and read meter.

   d. Check voltage drop.

   (NOTE: If the voltage drop exceeds 0.4 volts, excessive resistance is indicated.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #1 — REMOVE AND REPLACE A STARTER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Disconnected battery.	______	______
3. Removed cables and electrical wires and labeled.	______	______
4. Removed starter from engine.	______	______
5. Cleaned starter and block mounting surfaces.	______	______
6. Installed starter and tightened bolts.	______	______
7. Repositioned starter wires and cables in the correct place and tightened nuts securely.	______	______
8. Checked all connections.	______	______
9. Replaced battery cable.	______	______
10. Started engine to check starter action.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Starter operates properly.				
	4	3	2	1
All connections are clean and tight.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #2 — DISASSEMBLE, TEST, AND REASSEMBLE A STARTER

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Cleaned starter before disassembly.	______	______
3. Marked starter housings.	______	______
4. Removed bolts from the commutator end frame.	______	______
5. Disconnected the field coil from the brush holders.	______	______
6. Removed the lever and drive housing.	______	______
7. Removed the armature.	______	______
8. Removed starter drive from the armature.	______	______
9. Removed starter brushes.	______	______
10. Cleaned all starter components.	______	______
11. Inspected starter bushing and replaced if required.	______	______
12. Inspected brushes and replaced if required.	______	______
13. Inspected the starter drive and replaced if required.	______	______
14. Inspected armature commutator.	______	______
15. Tested the armature for short circuits.	______	______
16. Checked armature for grounds.	______	______
17. Checked armature shaft runout.	______	______
18. Checked field coil for opens.	______	______
19. Checked field coil for grounds.	______	______
20. Replaced or repaired any parts that were worn or damaged.	______	______
21. Lubricated all bushings, wicks and oil reservoirs.	______	______
22. Reassembled starter in the correct order.	______	______
23. Checked and adjusted pinion clearance.	______	______
24. Tested starter for operation.	______	______
25. Checked in/put away tools and materials.	______	______
26. Cleaned the work area.	______	______
27. Used proper tools correctly.	______	______
28. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
29. Practiced safety rules throughout procedure.	______	______
30. Provided satisfactory responses to questions asked.	______	______

JOB SHEET #2 PRACTICAL TEST

EVALUATOR'S COMMENTS: ____________________

____

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Testing procedures and test equipment were used correctly.				
	4	3	2	1
Starter motor performs properly.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #3 — TEST A STARTER MOTOR (NO-LOAD)

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Connected starter to battery.	______	______
3. Connected ammeter.	______	______
4. Connected switch.	______	______
5. Connected voltmeter.	______	______
6. Connected carbon pile resistor.	______	______
7. Used tachometer.	______	______
8. Performed no-load test.	______	______
9. Compared the readings of meters with technical manual.	______	______
10. Came to a conclusion on test results.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Made all connections correctly.				
	4	3	2	1
Student's evaluation is correct.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #4 — REBUILD AND TEST A STARTER SOLENOID

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed the screws in terminal plate.	______	______
3. Removed the screw from the pull in winding wire.	______	______
4. Removed contact disk and rod.	______	______
5. Removed terminal studs.	______	______
6. Cleaned and inspected and repaired or replaced all components.	______	______
7. Reassembled solenoid.	______	______
8. Checked solenoid hold-in winding.	______	______
9. Checked pull-in winding.	______	______
10. Compared test results with specifications.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
All components are clean and installed properly.				
	4	3	2	1
Testing procedures and test equipment were used correctly.				
	4	3	2	1
Student's evaluation is correct.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

PRACTICAL TEST
JOB SHEET #5 — CHECK VOLTAGE DROP IN A STARTER CIRCUIT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Made voltmeter connection on insulated cables.	______	______
3. Cranked engine and read voltage drop.	______	______
4. Made voltmeter connections for the solenoid contacts.	______	______
5. Cranked engine and read voltage drop.	______	______
6. Made voltmeter connections for ground cables.	______	______
7. Cranked engine and read voltage drop.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Testing procedures and test equipment were used correctly.				
	4	3	2	1
Student's evaluation of test results is correct.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

STARTING SYSTEMS AND CIRCUITS
UNIT V

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Ends of a magnet in the field frame assembly of a starting motor	1. Armature
_____b.	Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings	2. Brushes
_____c.	Main drive of starter motor; converts electrical energy into mechanical energy	3. Cemf
_____d.	Metal segments attached to ends of wire loops to form contact surface on armature	4. Commutator
_____e.	Sliding contacts to feed electrical energy from battery to commutator	5. Field winding
_____f.	Small gear that meshes with a larger gear	6. Inertia
_____g.	Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel	7. Motor swtich
_____h.	Any switch that closes the circuit between the battery and starter motor	8. Pinion
_____i.	Tendency of a body in motion to remain in motion	9. Pole pieces
_____j.	Counter electromotive force	10. Solenoid
_____k.	The drop, or current used in cables	11. Starter switch
_____l.	Activates the motor switch	12. Voltage drop

2. List three types of starting systems.

a. ____

b. ____

c. ____

TEST

3. List two sources of compressed air for air starting motors.

   a. ______________________________

   b. ______________________________

4. Select from the following list components of a gasoline starting system by placing an "X" beside each correct component.

   _____a. Motor switch

   _____b. Clutch

   _____c. Drive pinion

   _____d. Oil heater

   _____e. Gear box

   _____f. Gasoline engine

5. Select from the following list types of starting aids by placing an "X" beside each correct type.

   _____a. Oil heater

   _____b. Block heater

   _____c. Clutch

   _____d. Glow plug

   _____e. Starter switch

   _____f. Starting fluid

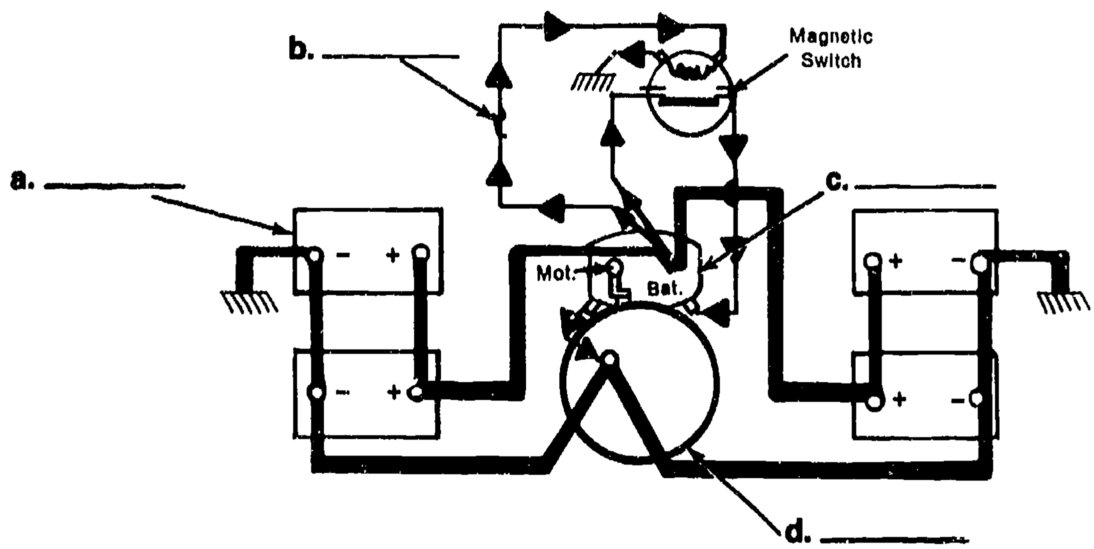
6. State the purpose of an electrical starting circuit.

   ____

   ____

TEST

7. Label the major parts in an electrical starting circuit.



8. Match parts related to a starting circuit with the correct functions.

______a.	Supplies energy for the circuit	1. Battery
______b.	Activates the circuit	2. Motor switch
______c.	Closes circuit to motor and engages motor drive with flywheel	3. Starting motor
		4. Starter switch
______d.	Drives flywheel to start engine	

9. Select the major parts of a starting motor by placing an "X" beside the correct part.

______a. Motor switch

______b. Shoe pole

______c. Field frame assembly

______d. Armature

______e. Rotor

______f. Drive mechanism

TEST

10. Match component parts of a starting motor with their correct functions.

_____a.	Forms a magnetic field of force around armature	1. Armature
_____b.	Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding	2. Brushes
_____c.	Converts electrical energy into mechanical energy to drive mechanism to crank engine	3. Commutator
_____d.	Forms contact surface for battery to feed electrical current through armature	4. Field winding
_____e.	Sliding contacts which feed electrical energy to the commutator	5. Pole shoe

11. Complete the following statement concerning the conversion of electrical energy into mechanical energy by filling in the blanks correctly with the following words: Rotate, conductor, magnetic.

    Current carrying ____________ formed in a loop and mounted on a shaft, will cause the shaft to ____________ when placed inside a ____________ field.

12. Select true statements concerning how a starting motor is kept running by placing an "X" beside each statement that is true.

    _____a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn.

    _____b. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts which causes the current to flow in the opposite direction in the armature windings.

13. Arrange in order the current flow in an electrical starting motor circuit by placing the correct sequence number beside each step.

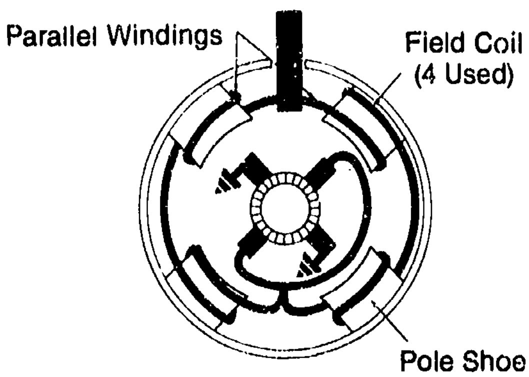
    _____a. The solenoid closes allowing current to flow from the battery terminal of the solenoid to the motor terminal of the solenoid, and at the same time, engages the starter drive with the flywheel. Current then passes through the starter and back to ground.

    _____b. With the key switch in the "start" position, current flows from the battery terminal of the starter through the magnetic switch and to ground.

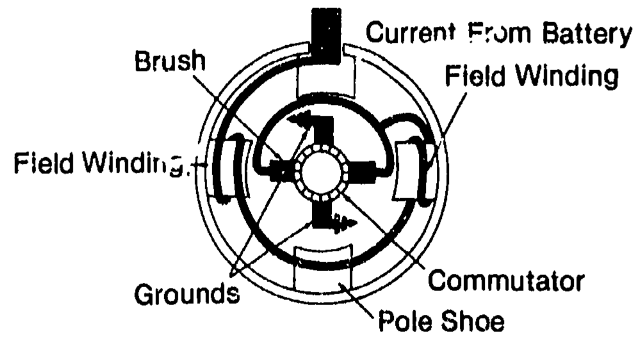
    _____c. The magnetic switch closes, allowing current to flow from the battery terminal of the solenoid to the switch terminal of the solenoid.

TEST

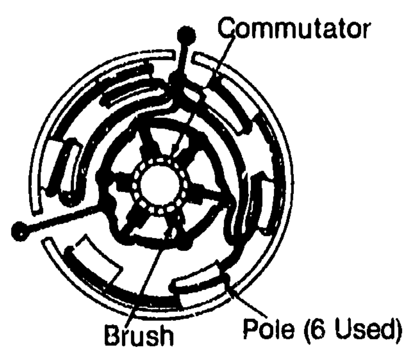
14. Identify four types of starter field circuits.



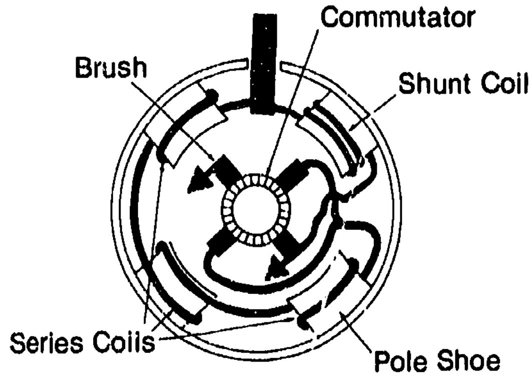
a. ______________________



b. ______________________



c. ______________________



d. ______________________

15. Match the types of starter field circuits with the current flow in each type circuit.

_____a.	Current flows through all field windings before it flows through the two insulated brushes to the armature.	1. Compound-wound
_____b.	Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel.	2. Parallel-wound
_____c.	One-third of the current flows through each pair of field windings to one of the three insulated brushes.	3. Series-parallel-wound
_____d.	One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds.	4. Series-wound

TEST

16. List four types of starting motor switches.

    a. ____________________

    b. ____________________

    c. ____________________

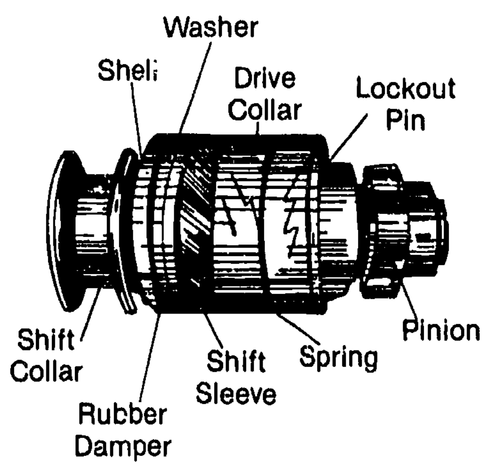
    d. ____________________

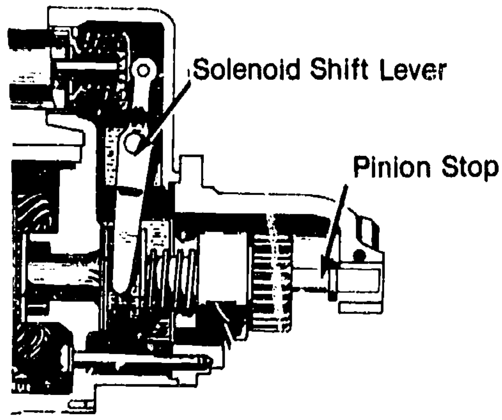
17. Explain two ways starter drives are engaged.

    a. ____________________

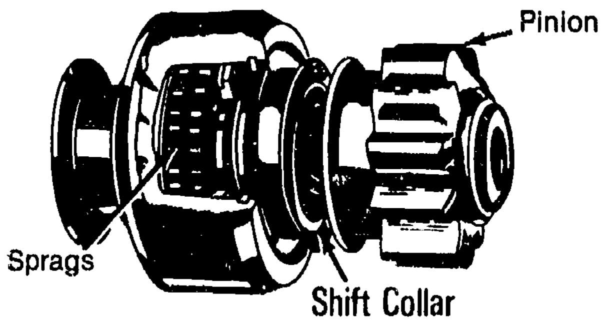
    b. ____________________

18. Identify three types of electromagnetic or lever shift drives.





a. ____________________ b. ____________________



c. ____________________

TEST

19. Arrange in order the steps in the operation of a series-parallel switch by placing the correct sequence number beside each step.

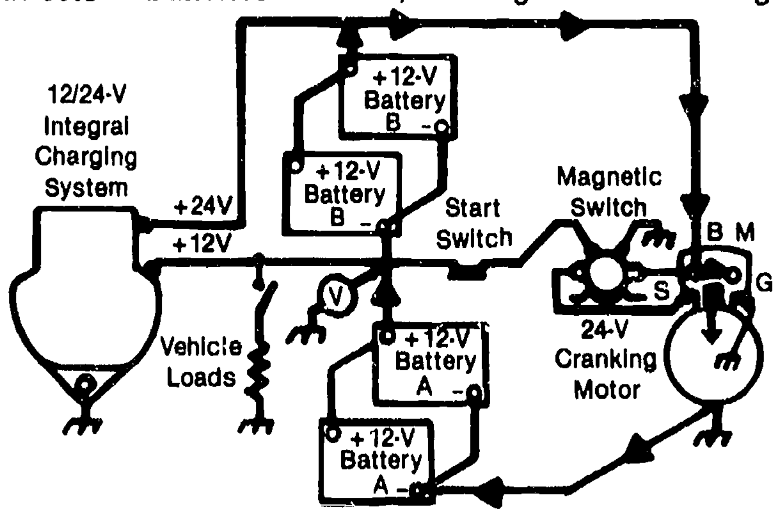
_____a. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over.

_____b. Starter switch closes, connecting two 12 volt batteries in series with the starting motor.

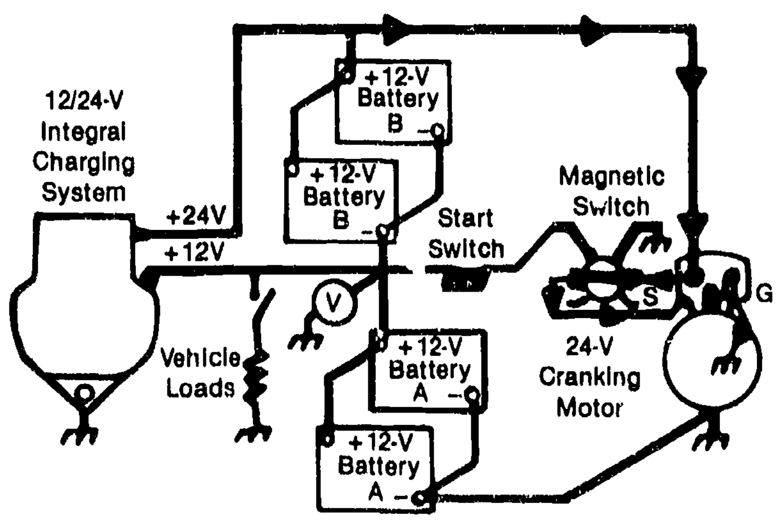
_____c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation.

20. Arrange in order the steps in the operation of a transformer-rectifier unit by placing the correct sequence number beside each step.

_____a. This action engages the solenoid and current then flows from the battery terminal of solenoid to the motor terminal, through the starter to ground, and into the negative post of the batteries marked A. This action connects both sets of batteries in series, creating 24 V for starting.

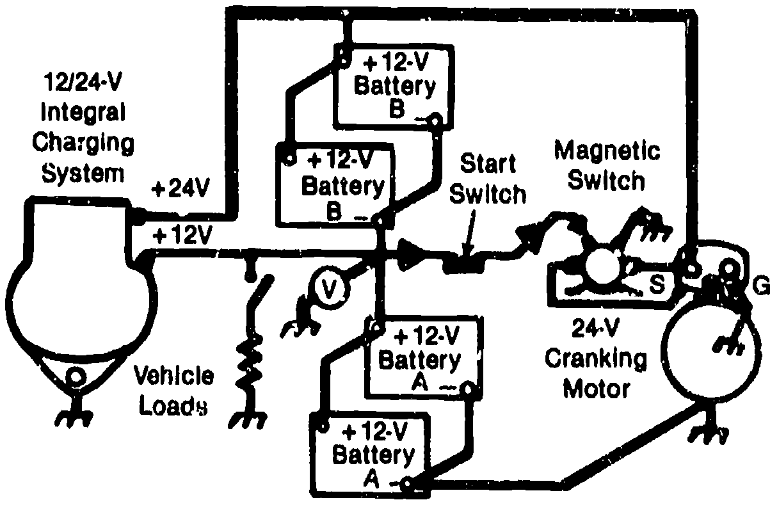


_____b. The current for the solenoid switch and for cranking flows from the positive posts of the "B" batteries to the battery terminal on the solenoid switch, to and over the magnetic switch disk, to insulated terminals, and through the solenoid windings to ground.



TEST

_____c. The operator closes the start switch, forcing 12 V from the batteries marked "A" through the magnetic switch, closing the cranking motor actuating circuit.



(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

21. Demonstrate the ability to:

    a. Remove and replace a starter. (Job Sheet #1)

    b. Disassemble, test, and reassemble a starter. (Job Sheet #2)

    c. Test a starter motor (no-load). (Job Sheet #3)

    d. Rebuild and test a starter solenoid. (Job Sheet #4)

    e. Check voltage drop in a starter circuit. (Job Sheet #5)

STARTING SYSTEMS AND CIRCUITS
UNIT V

ANSWERS TO TEST

1. a. 9 g. 10
   b. 5 h. 7
   c. 1 i. 6
   d. 4 j. 3
   e. 2 k. 12
   f. 8 l. 11

2. a. Electric motors
   b. Gasoline engines
   c. Air starters

3. a. Separate engine and compressor
   b. Air from exhaust manifold on highway diesel tractors

4. b, c, e, f

5. a, b, d, f

6. Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine.

7. a. Battery
   b. Starter switch
   c. Motor switch
   d. Starting motor

8. a. 1
   b. 4
   c. 2
   d. 3

9. a, c, d, f

10. a. 5
    b. 4
    c. 1
    d. 3
    e. 2

11. Conductor, rotate, magnetic

12. a, b

ANSWERS TO TEST

13. a. 3
    b. 1
    c. 2

14. a. Parallel-wound
    b. Series-wound
    c. Series-parallel-wound
    d. Compound-wound

15. a. 4
    b. 2
    c. 3
    d. 1

16. a. Manual
    b. Solenoid
    c. Magnetic
    d. Series-parallel

17. Explanation should include:
    a. Inertia of armature acting through drive mechanism
    b. Electromagnetic plunger to mechanically shift pinion into mesh

18. a. Positork®
    b. Overrunning clutch
    c. Sprag clutch drive

19. a. 2
    b. 1
    c. 3

20. a. 3
    b. 2
    c. 1

21. Performance skills evaluated to satisfaction of instructor

IGNITION CIRCUITS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to remove, service, and replace components of an ignition circuit. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to ignition circuits with their correct definitions.
2. Explain the purpose of an ignition circuit.
3. Identify components of an ignition circuit.
4. Match components of an ignition circuit with their correct functions.
5. Distinguish between primary and secondary ignition circuit components.
6. Identify components of a distributor.
7. Arrange in order steps in the operation of an ignition circuit beginning with the battery through one complete cycle.
8. Identify components of a distributor with a built-in governor.
9. Arrange in order steps in the operation of a governed distributor.
10. Distinguish between transistorized and capacitive discharge ignition systems.

OBJECTIVE SHEET

11. Match major components of an electronic ignition system with their functions.

12. Select true statements concerning general precautions for electronic ignition systems.

13. Demonstrate the ability to:

    a. Remove and install a distributor. (Job Sheet #1)

    b. Remove and replace contact points and condenser. (Job Sheet #2)

    c. Adjust dwell on an externally adjustable distributor. (Job Sheet #3)

    d. Check and set ignition timing. (Job Sheet #4)

    e. Remove, service, and replace spark plugs. (Job Sheet #5)

IGNITION CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss the different methods of ignition bypass.

2. Show electronic parts to students and explain their operation.

3. Discuss spark plug components.

4. Discuss ignition cables.

5 Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Electronic Engine Controls Manual.* Radnor, PA: Chilton Book Co., 1985.

B. Foutes, William A. *Diesel Mechanics: Electrical Systems.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

REFERENCES USED IN DEVELOPING THIS UNIT

C. *Fundamentals of Service: Electrical Systems.* 4th ed. Moline, IL: Deere and Co., 1979.

D. *Truck and Diesel Repair Manual.* 34th ed. New York, NY: Motor, 1981.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Text**

Chilton's Guide to Electronic Engine Controls
Order #CH-7535
Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92628-0798

B. **Filmstrips**

1. *The Ignition System Explained*
   Order #B-401
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92628-0798

2. *Electronic Ignition Systems*
   Order #D-E1000
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92628-0798

IGNITION CIRCUITS
UNIT VI

INFORMATION SHEET

I. **Terms and definitions**

A. Coil polarity — A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground

Example: Negative-ground systems — The negative primary terminal of coil is connected to distributor. Positive-ground systems — The positive primary terminal is connected to the distributor.

B. Condenser — A unit installed between the breaker points and coil to prevent arcing

(NOTE: A condenser has the ability to absorb and retain surges of electricity.)

C. Dwell — Number of degrees of distributor cam rotation that the ignition points are closed

D. Electronic ignition system — Ignition system using a control unit and magnetic pickup to open and close the primary circuit

E. Electronic module — A switching device that opens and closes the ignition to primary ground circuit

F. Primary ignition circuit — Low voltage circuit which energizes the ignition coil

G. Secondary ignition circuit — High voltage circuit which produces electrical current to jump spark plug gap

H. Spark plug — Provides the gap for the high voltage spark to ignite the fuel/air mixture

I. Timing — Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power

J. Timing marks — Marks used to synchronize ignition circuit so that plugs will fire at precise time

(NOTE: Timing marks are usually located on the vibration damper or flywheel.)

INFORMATION SHEET

II. **Purpose of an ignition circuit** — The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder.

III. **Components of an ignition circuit** (Transparency 1)

A. Battery

B. Ignition switch

C. Primary resistance unit

D. Ignition coil

E. Contact points

F. Condenser

G. Distributor

H. Breaker cam

I. Spark-advance mechanism

(NOTE: There are two types of spark-advance mechanisms — vacuum and mechanical. Engine vacuum controls timing advance in relation to engine load. Mechanical advance changes engine timing according to engine speed.)

J. Rotor

K. Distributor cap

L. Spark plug

M. Primary ignition wire

N. Secondary ignition cable

O. Ignition bypass circuit

IV. **Components of an ignition circuit and their functions** (Transparency 1)

A. Battery — Source of electrical power

B. Ignition switch — Opens and closes the primary circuit between battery and contact points

C. Primary resistance unit — Reduces voltage in the primary circuit to protect the contact points

INFORMATION SHEET

D. Ignition coil — Transforms low voltage into high voltage necessary to jump the spark plug gap

E. Contact points — Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

F. Condenser — Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow

G. Distributor — Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

H. Breaker cam — Opens and closes the contact points

I. Spark-advance mechanism — Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

J. Rotor — Takes the high voltage current from the coil and directs it to the correct cylinder

K. Distributor cap — Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

L. Spark plug — Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture

M. Primary ignition wire — Carries low voltage from the battery through the ignition coil to the points

N. Secondary ignition cable — Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

O. Ignition bypass circuit — Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

V. **Ignition circuit components**

A. Primary — Low voltage circuit (Transparency 2)

1. Battery
2. Ignition switch
3. Resistance unit
4. Primary winding of the coil

INFORMATION SHEET

5. Contact points

6. Condenser

7. Low voltage wire that connects the units

B. Secondary — High voltage circuit (Transparency 3)

1. Secondary winding of the coil

2. Distributor cap

3. Rotor

4. Spark plug

5. High voltage wire that connects the units

VI. **Components of a distributor** (Transparency 4)

A. Distributor cap

B. Rotor

C. Centrifugal advance mechanism

D. Condenser

E. Vacuum advance unit

F. Breaker plate

G. Distributor cam

H. Contact points

I. Distributor housing

J. Primary lead wire

K. Distributor drive gear

VII. **Operation of an ignition circuit**

A. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground. (Transparency 5)

B. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup. (Transparency 6)

INFORMATION SHEET

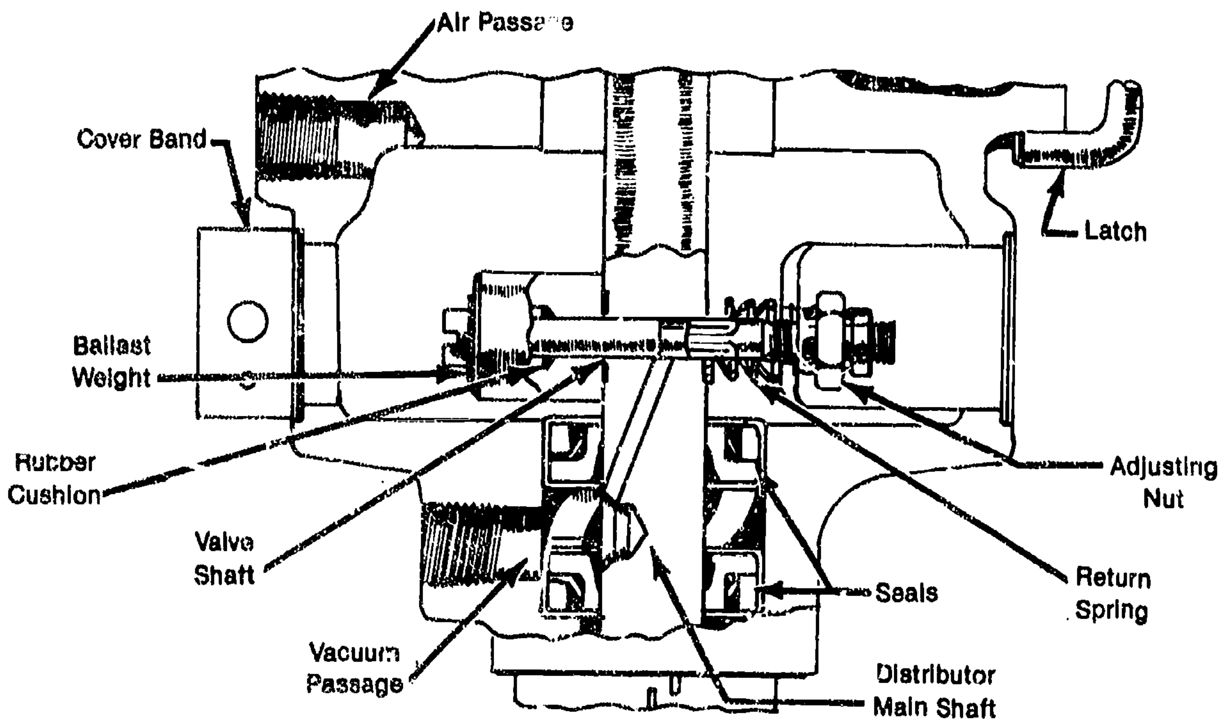
C. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current. (Transparency 7)

D. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge. (Transparency 8)

E. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground. (Transparency 9)

VIII. Components of a distributor with a built-in governor

(NOTE: Except for the built-in maximum speed governor, this distributor is similar to the standard distributor.)



Built-In Engine Maximum Speed Governor Mechanism

Reprinted with permission of Delco Remy Division, GM Corp.

A. Valve shaft

B. Ballast weight

C. Adjusting nut

D. Return spring

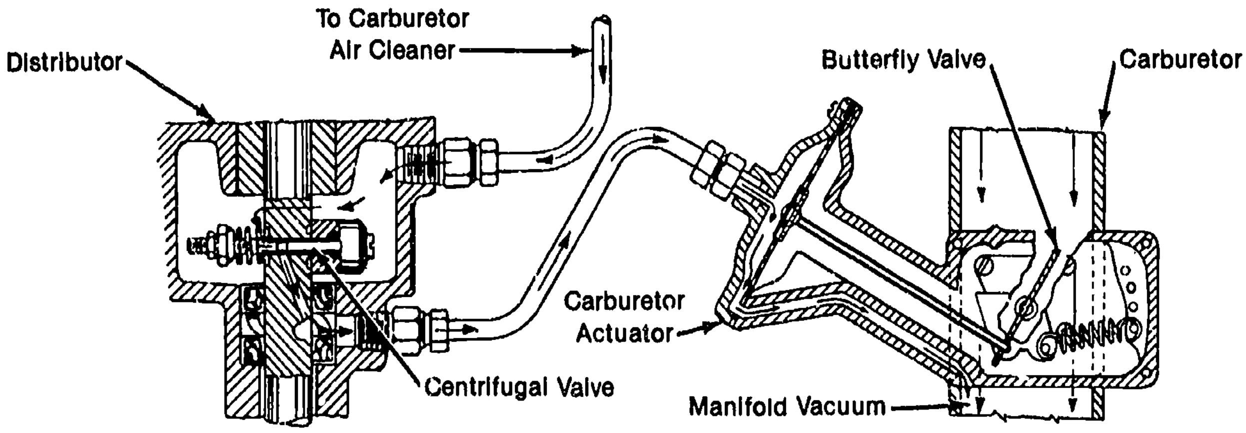
E. Cover band

INFORMATION SHEET

IX. **Operation of a governed distributor** (Transparency 10)

A. Vacuum from the intake manifold draws air through the air cleaner, through the distributor and past the carburetor actuator. An overriding feature on the butterfly valve allows the foot pedal to control the butterfly valve position except when the actuator diaphragm pull is sufficient to overcome the opposing spring force.

B. When the distributor shaft revolves fast enough the centrifugal force of the weight pulls against the spring, causing the valve shaft to move transversely in the main shaft, restricting the flow of air.



Air Flow And Vacuum Connections Between Carburetor And Delco-Remy Governed Distributor (Typical)

C. When this restriction occurs, a vacuum is created in the carburetor actuator, causing it to move the butterfly valve in the carburetor, thereby governing the engine speed.

X. **Transistorized and capacitive discharge ignition systems**

(NOTE: Both variations are designed to increase primary voltage to coil and reduce voltage to points or eliminate points.)

A. Transistorized ignitions

1. Amplifier is included in circuit between points and ignition coil.

2. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil.

B. Capacitive discharge system

1. System contains special ignition distributor, amplifier, and special coil.

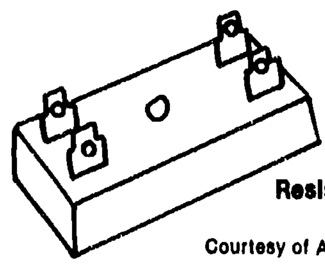
2. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil.

INFORMATION SHEET

XI. **Major components of an electronic ignition system and their functions** (Transparency 11)

(NOTE: The electronic ignition system functions the same as the conventional ignition system; however, in the electronic system, an electronic control unit and its sensory device, a magnetic pickup, does the job of the ignition points of the conventional system.)

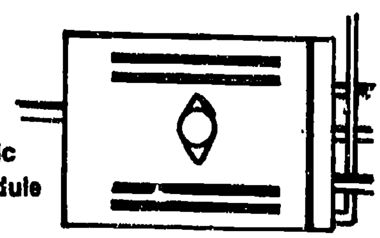
A. Resistor — Maintains constant primary current flow according to engine speed and is bypassed during cranking



Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

B. Control module — Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

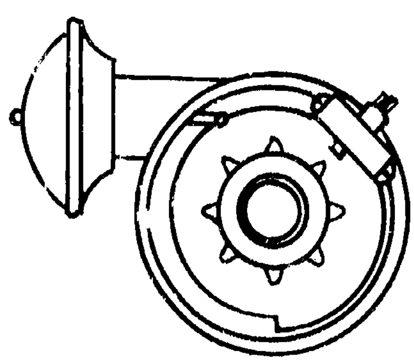
(NOTE: On Ford, Chrysler, and American Motors, this module is a separate unit, mounted firmly to the firewall or fender shield. On G.M. cars, it is self-contained within the distributor.)



Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

C. Magnetic pickup assembly — Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

D. Armature or reluctor — Rotates with the distributor shaft producing a voltage pulse in the magnetic pickup



Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

INFORMATION SHEET

XII. General safety precautions for electronic ignition systems

(NOTE: There are numerous variations in procedures, techniques, tools, and parts for servicing all the electronic ignition systems. An appropriate service manual will provide safe, reliable repair procedures.)

A. Always turn the ignition switch off when disconnecting or connecting any electrical connectors or components.

B. Never reverse the battery polarity or disconnect the battery with the engine running.

C. Disconnect the ignition switch feed wire at the distributor when making compression tests.

(NOTE: This will avoid arcing that may damage components, especially on computer-based ignition systems.)

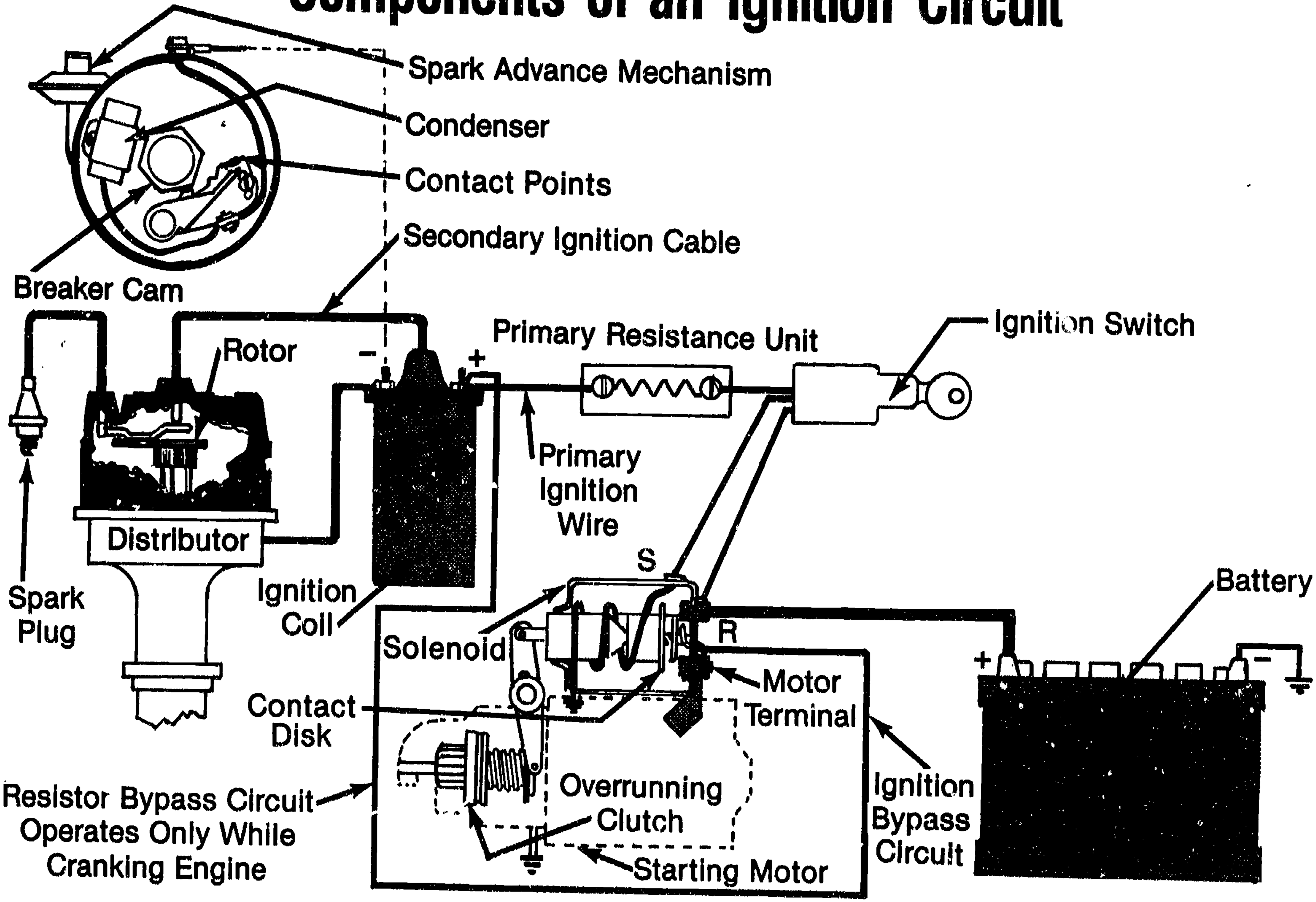
D. Check all replacement part numbers carefully.

(CAUTION: Installing the wrong component for a specific application can damage the system.)

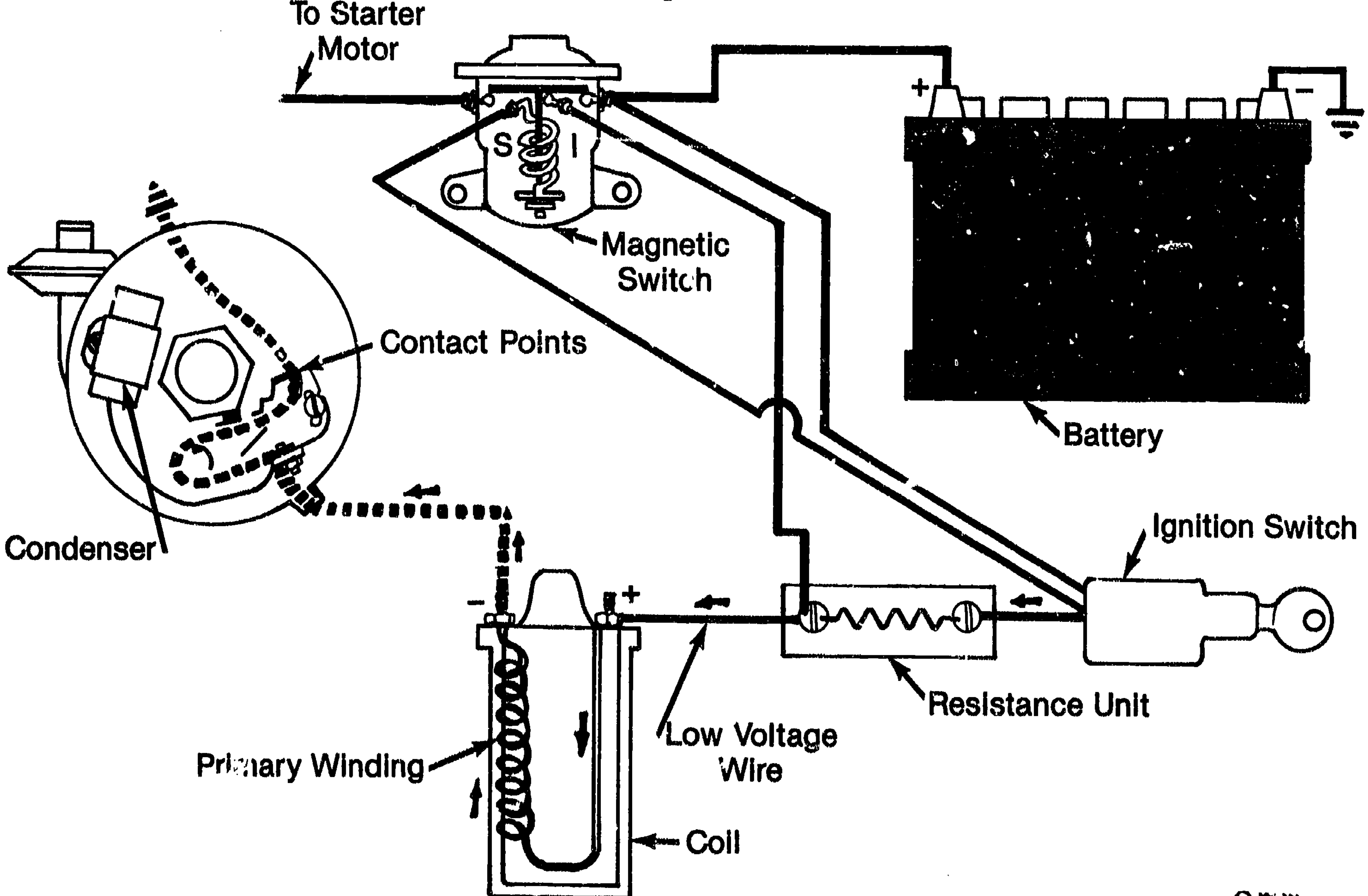
E. All manufacturer's instructions must be followed carefully when using test equipment.

(NOTE: Inaccurate readings and/or damage to ignition system components may result due to the use of improper test equipment.)

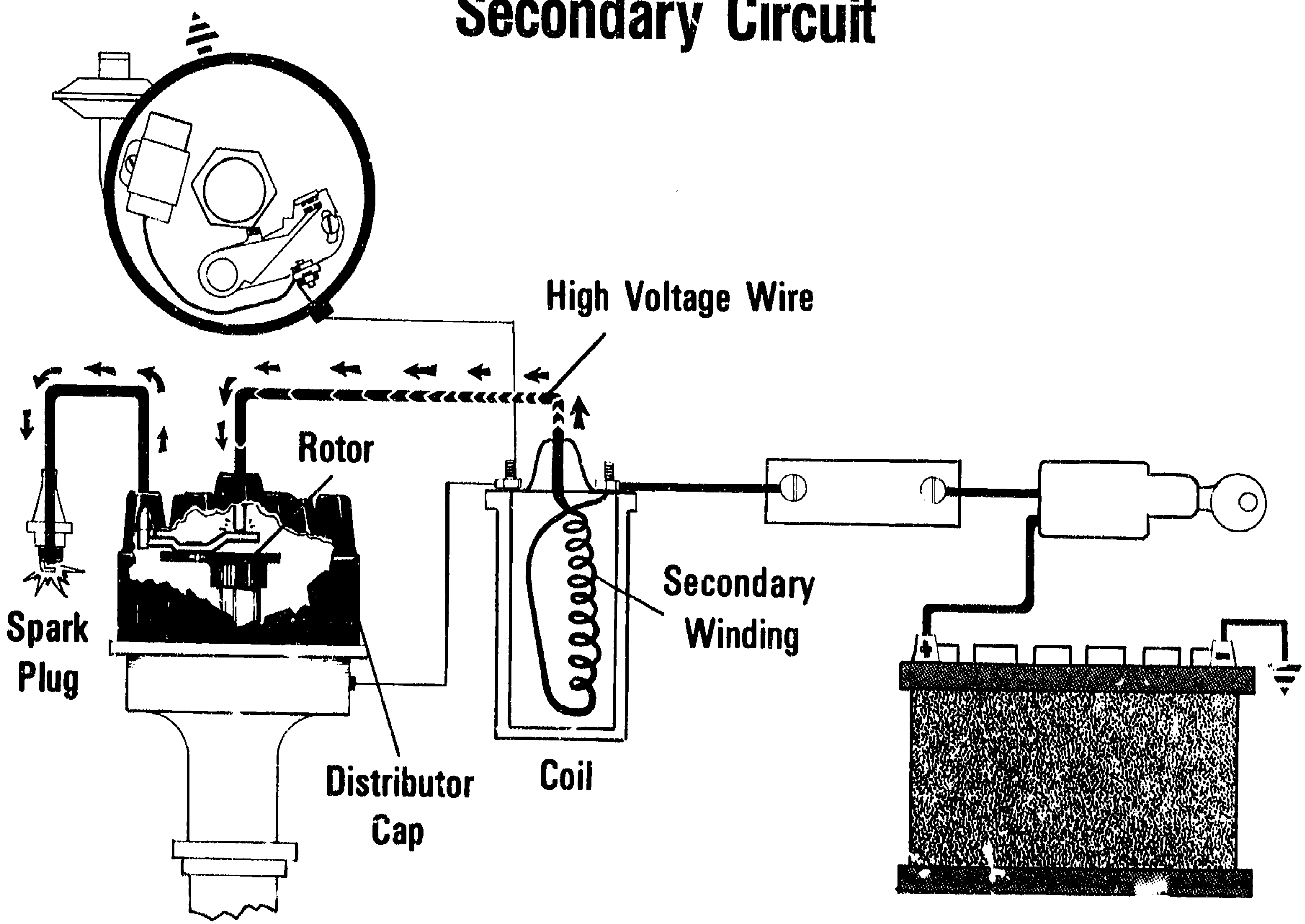
Components of an Ignition Circuit



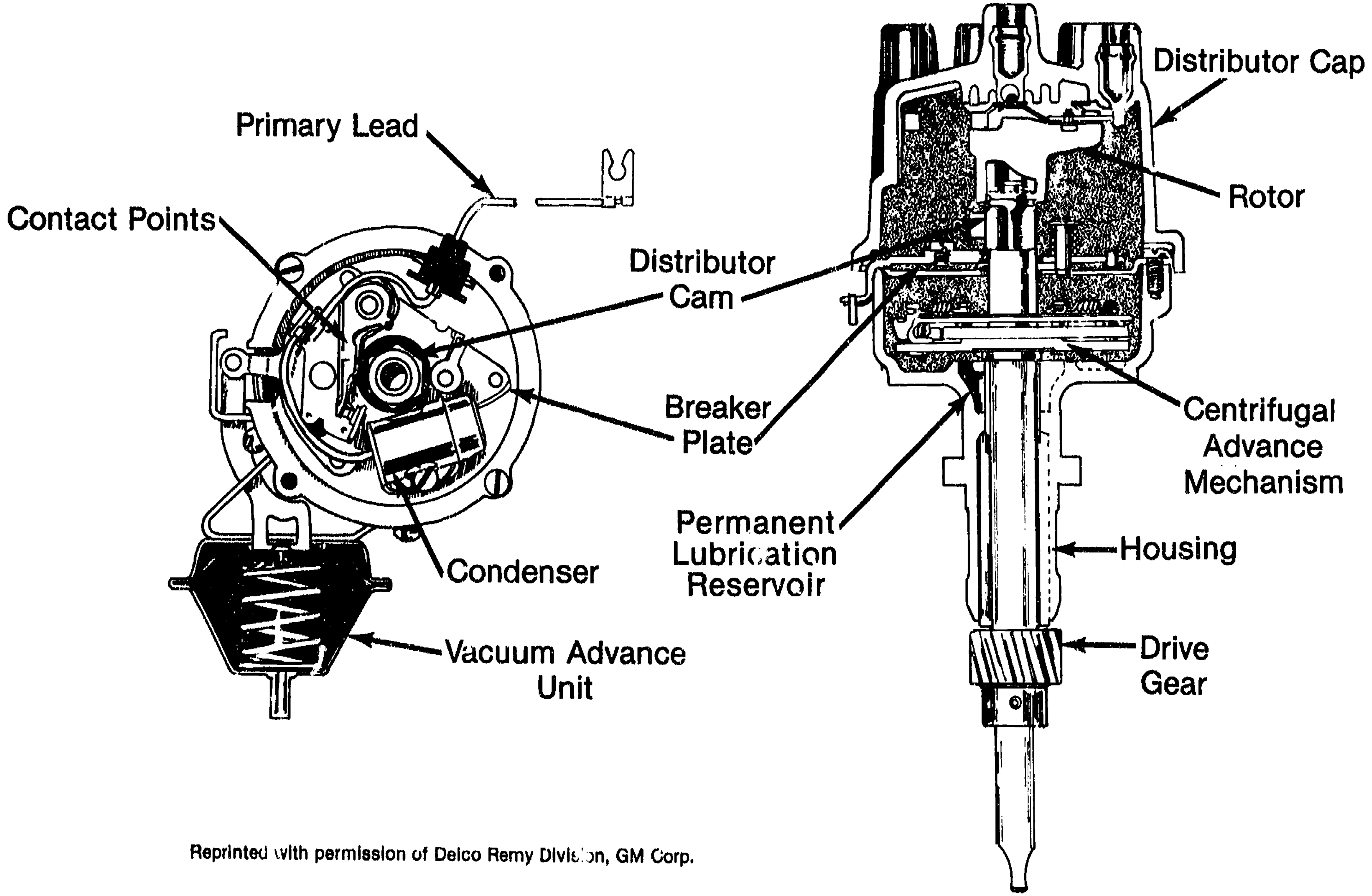
Primary Circuit



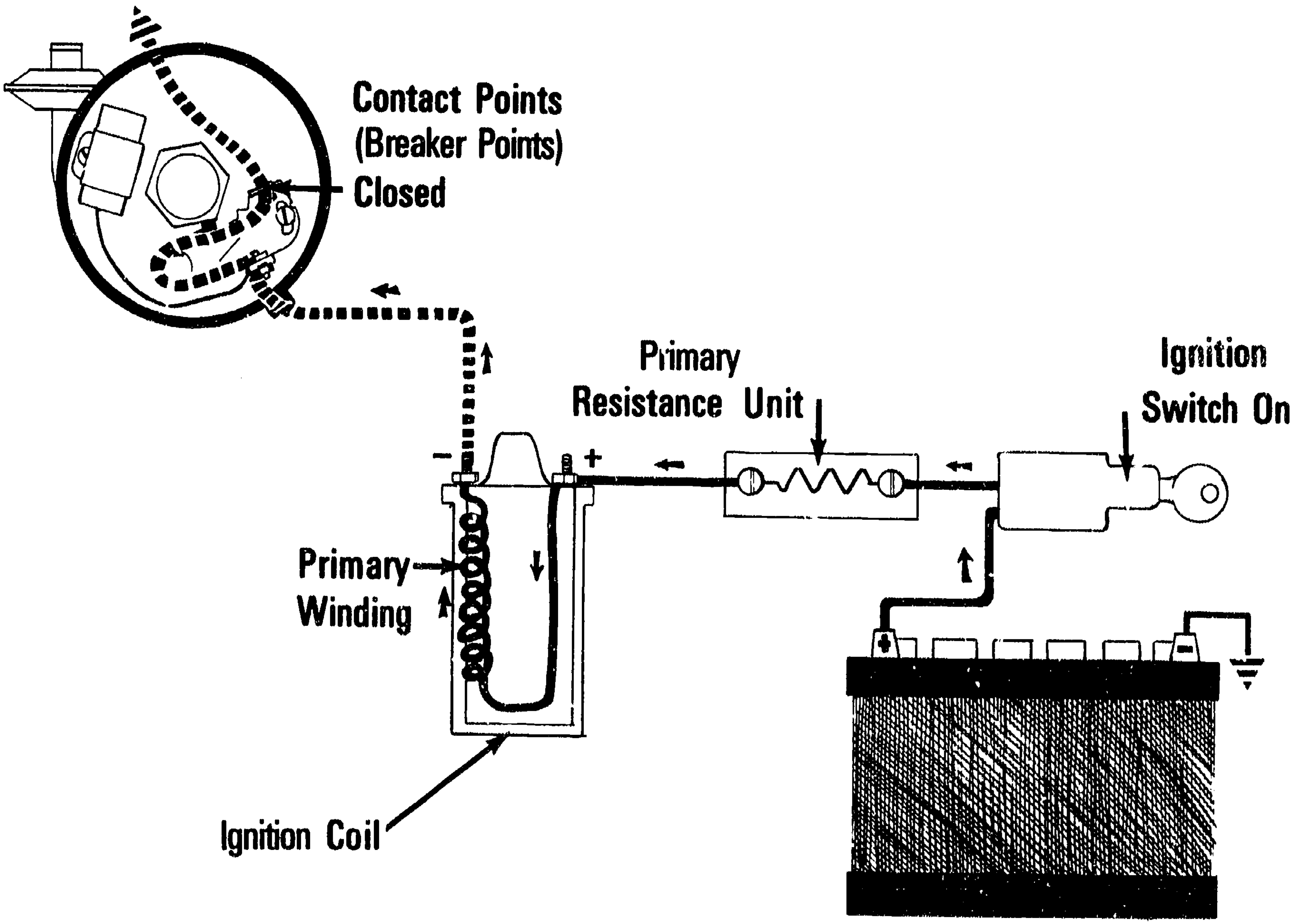
Secondary Circuit



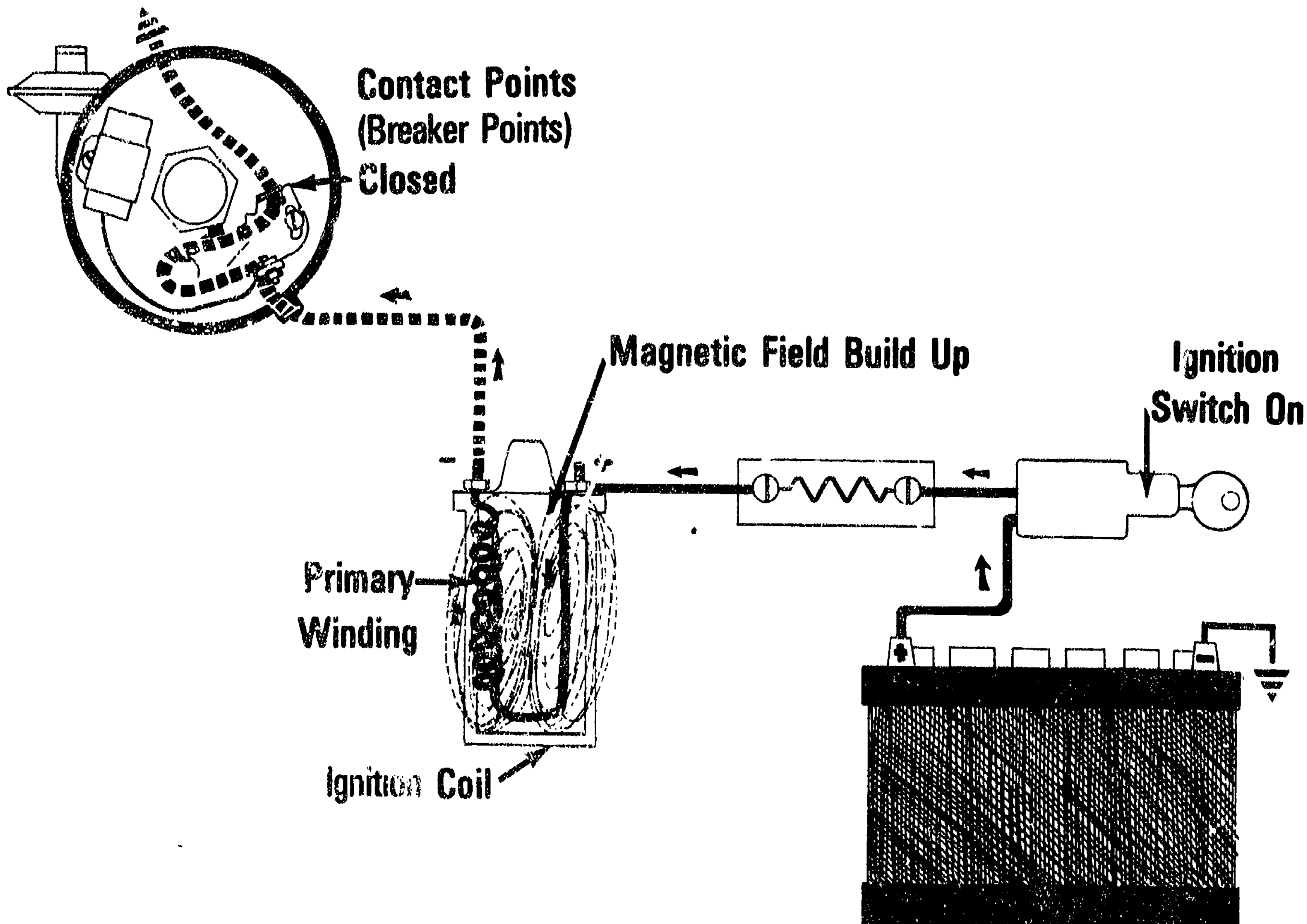
Components of a Distributor



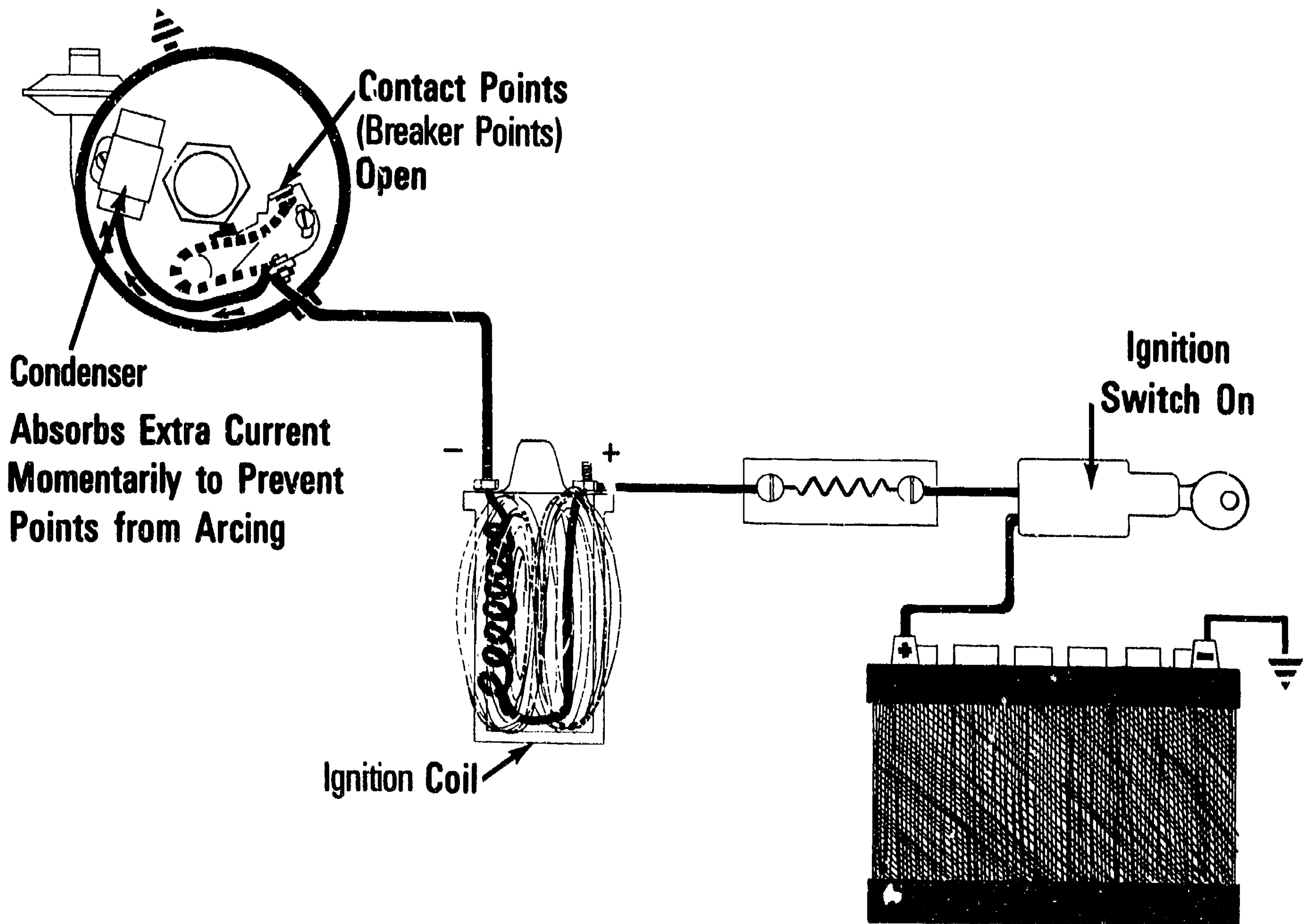
Operation of an Ignition Circuit — A



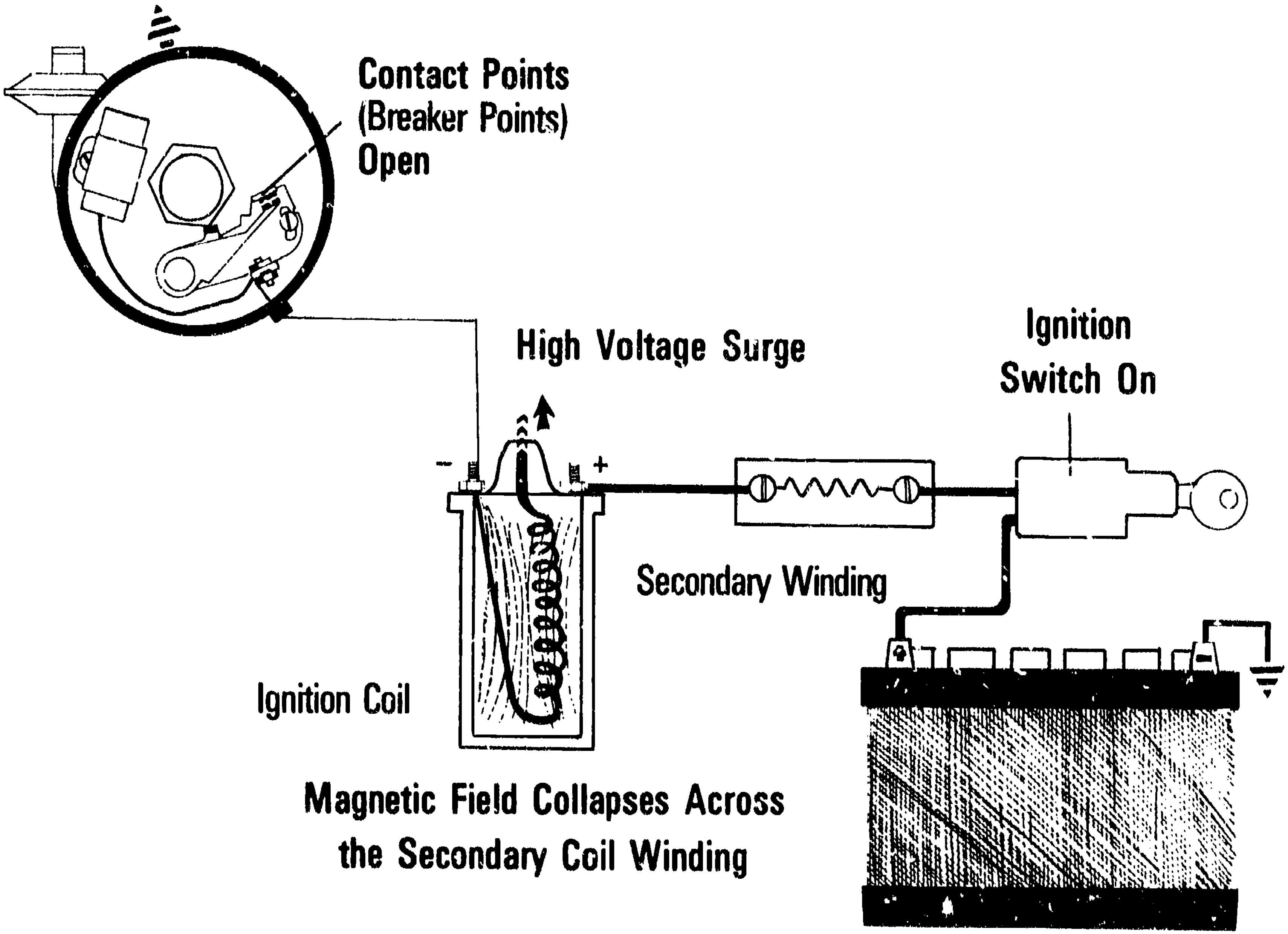
Operation of an Ignition Circuit — B



Operation of an Ignition Circuit — C

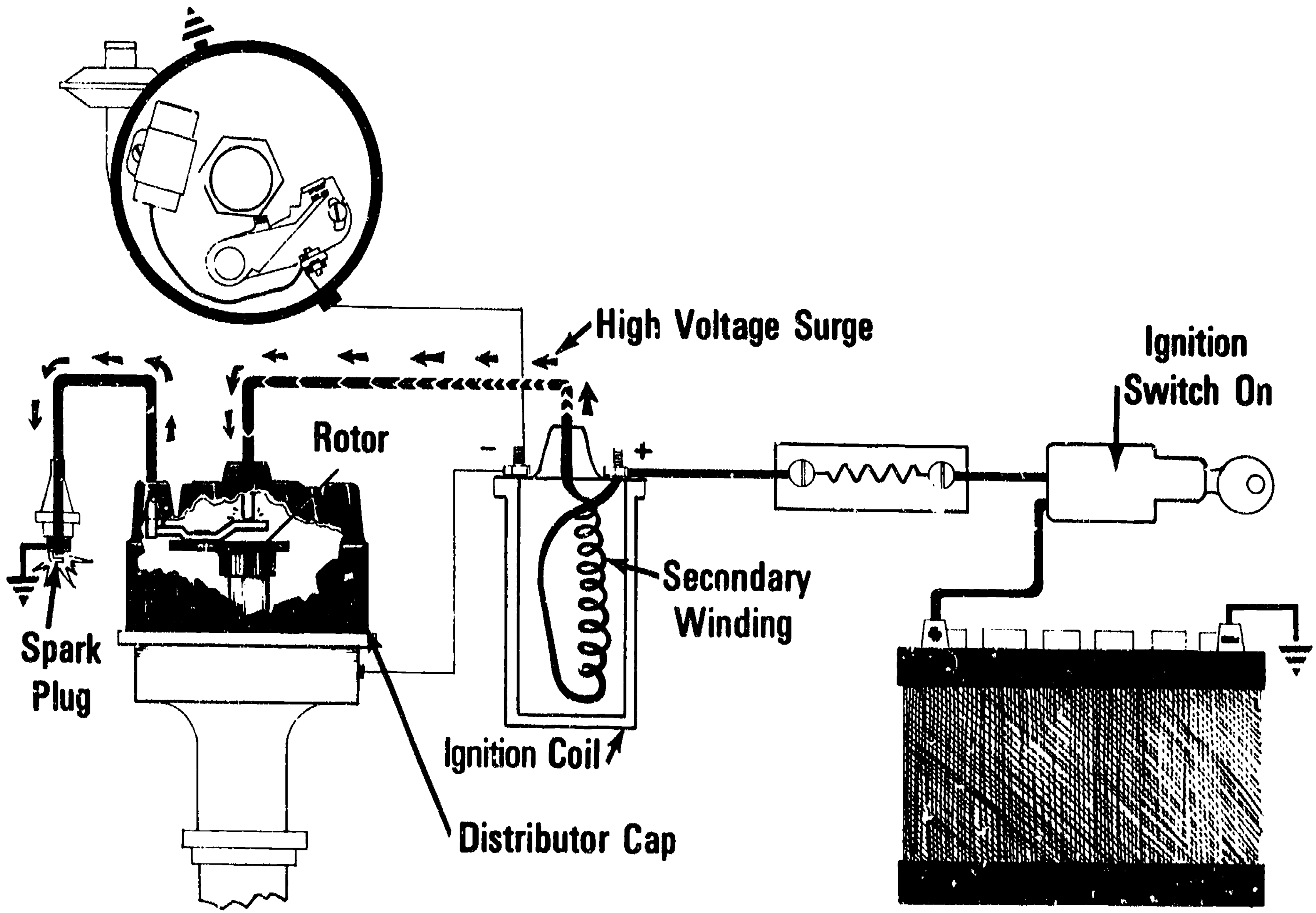


Operation of an Ignition Circuit — D



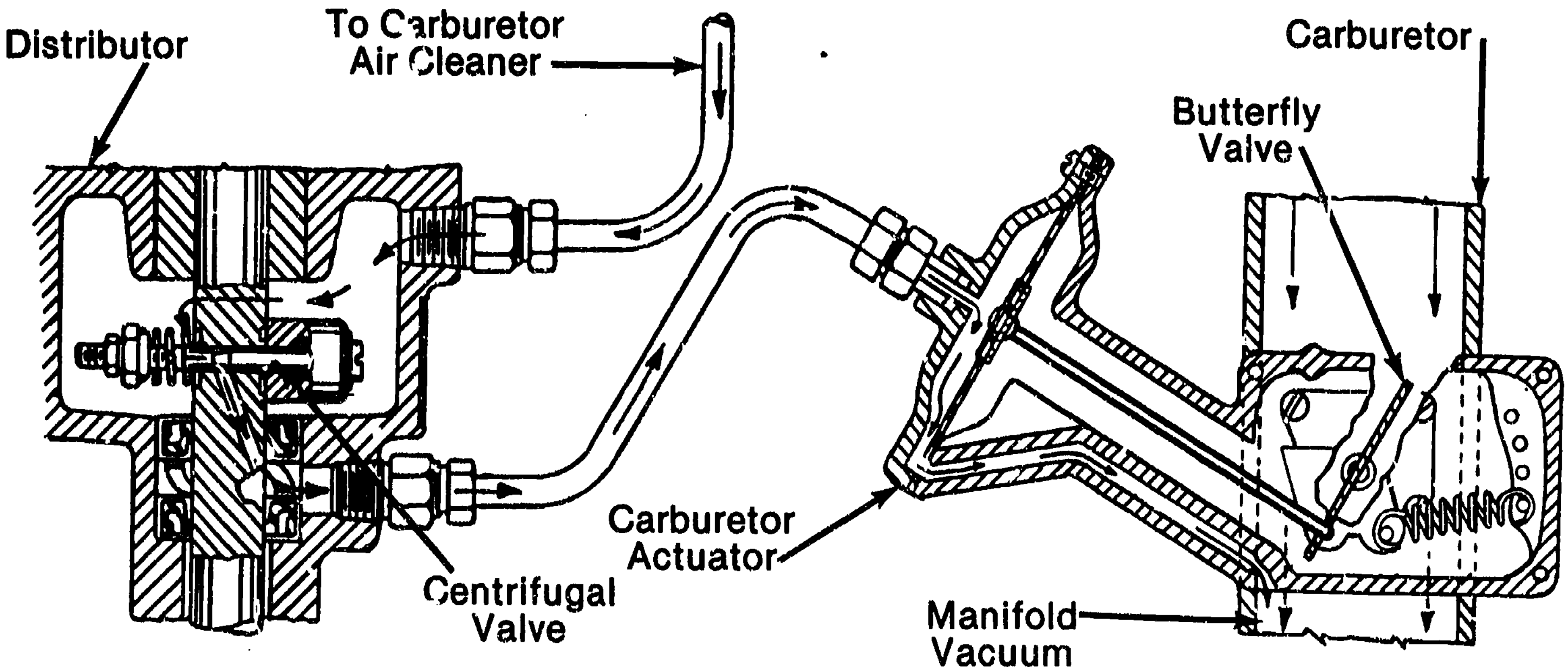
Magnetic Field Collapses Across the Secondary Coil Winding

Operation of an Ignition Circuit - E

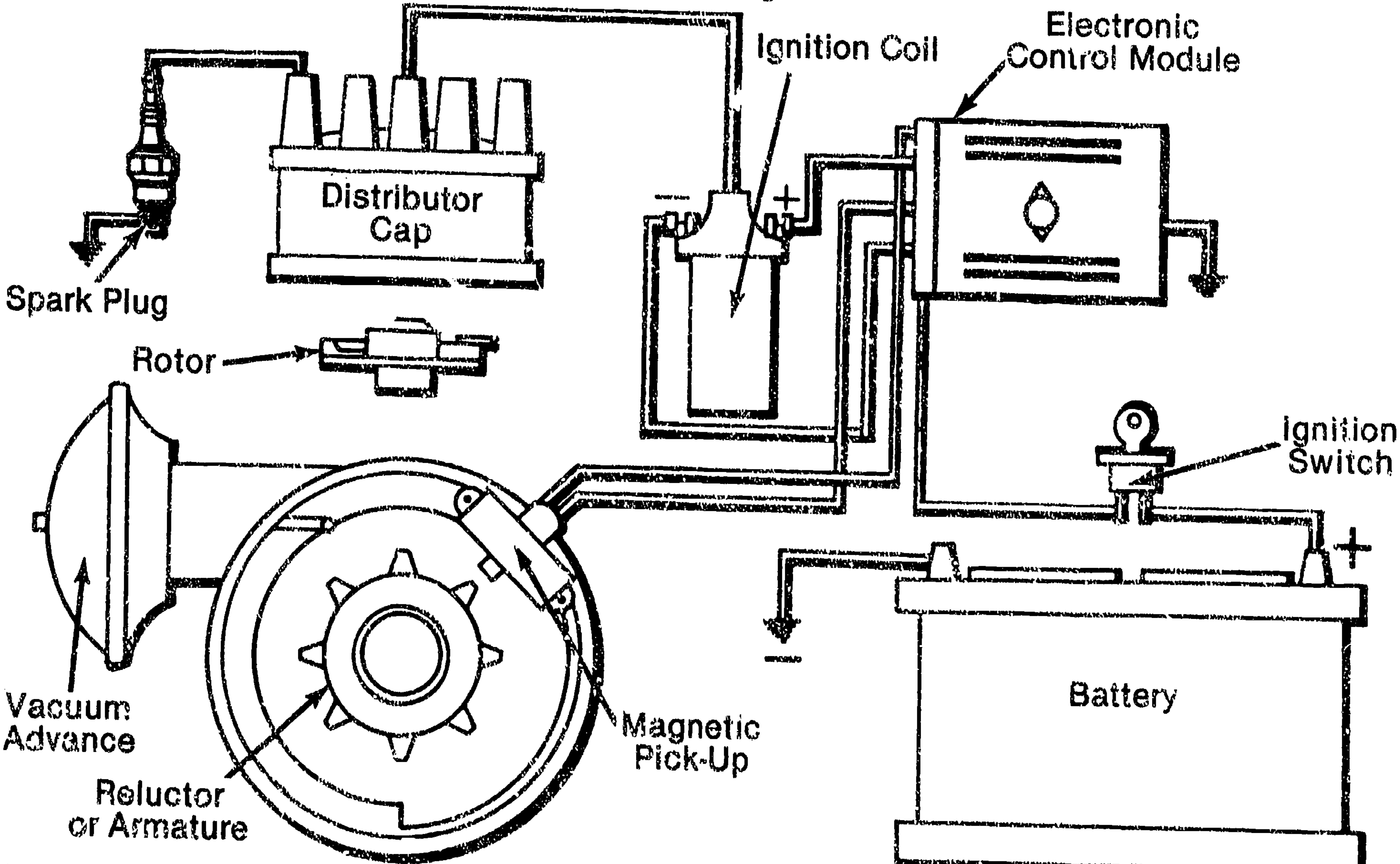


DE-303

Operation of a Governed Distributor



Major Components of an Electronic Ignition System



Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

IGNITION CIRCUITS
UNIT VI

JOB SHEET #1 — REMOVE AND INSTALL A DISTRIBUTOR

A. Tools and materials

1. Engine
2. Basic hand tool set
3. Set of ignition wrenches
4. Special distributor wrenches as required
5. Auxiliary starter button
6. Spark plug socket wrench
7. Shop towels
8. Safety glasses
9. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Remove distributor.

   a. Disconnect negative battery cable from battery.

   b. Remove air cleaner if required.

   c. Remove the distributor wire from coil or distributor as required.

   d. Remove the distributor cap and position out of the way.

   e. Mark position of the rotor.

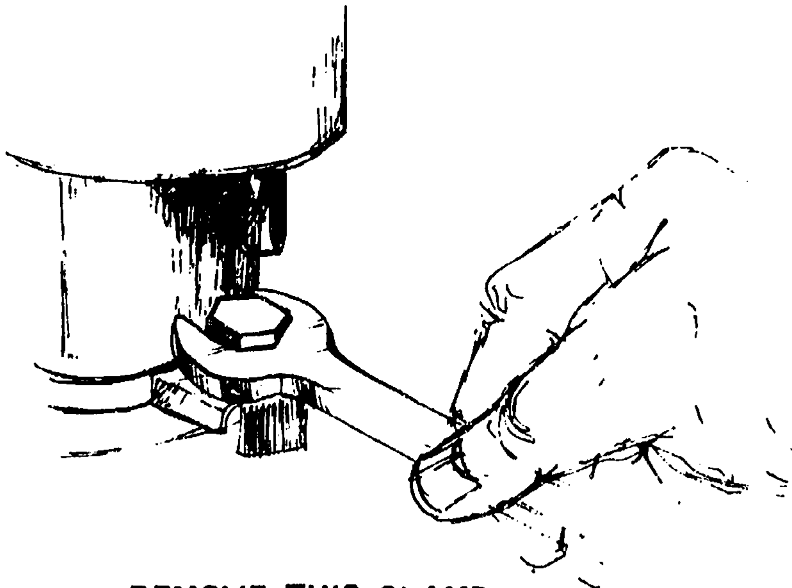
   (NOTE: It is necessary that the position be marked or indicated in some manner for re-installation.)

   f. Remove vacuum hose line from distributor and plug.

JOB SHEET #1

g. Remove distributor clamp screw and hold-down clamp. (Figure 1)

FIGURE 1



REMOVE THIS CLAMP

h. Pull distributor up slowly and check direction the rotor turns.

(NOTE: The amount the rotor turns and the direction it turns will be necessary for re-installation.)

i. Remove distributor from engine.

(NOTE: If engine is not disturbed while distributor is out, it can be reinstalled without turning engine.)

(CAUTION: Avoid dropping bolts, brackets, or foreign material into opening. Cover with a shop towel.)

j. Service distributor as required.

2. Install distributor.

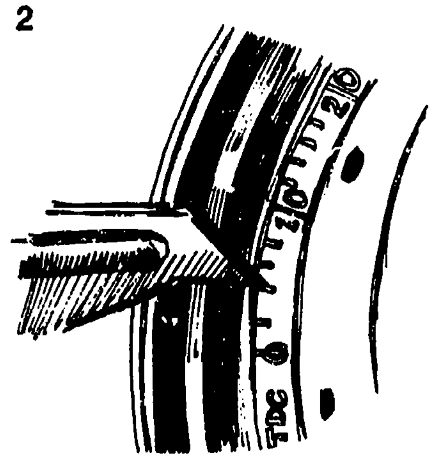
a. Remove number one cylinder spark plug.

b. Install auxiliary starter button, and crank the engine until compression is felt on number one cylinder.

JOB SHEET #1

c. Crank the engine with short movements until the timing marks on the fly-wheel index with the timing marks on the front cover. (Figure 2)

FIGURE 2



d. Place distributor in opening.

(NOTE: The rotor must be pointing in the same direction as it was before removal.)

e. Move distributor, if necessary, to engage the oil pump shaft.

(NOTE: Occasionally the distributor will not fall into place because the oil pump shaft has moved. The rotor should be positioned as close as possible to the beginning location and the engine rotated slightly until it falls into place. Some distributor drives will be driven by oil pump and gear mesh will not be necessary.)

f. Install hold-down clamp and clamp screw.

g. Static time point openings.

(NOTE: A connection between distributor side of coil and ground with a light or buzzer can be used.)

h. Tighten the hold-down screw slightly.

i. Replace vacuum lines.

j. Replace distributor cap and wires if removed.

k. Replace spark plugs and plug wires.

l. Replace distributor lead wire.

m. Check all connections for correct placement.

n. Start engine and check timing.

o. Check operation of automatic advance.

IGNITION CIRCUITS
UNIT VI

JOB SHEET #2 — REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

A. Tools and materials

1. Engine
2. Basic hand tool set
3. Ignition wrenches
4. Feeler gauges, .010-.025
5. Distributor cam lubricant
6. Point alignment tools
7. Timing light
8. Shop towels
9. Safety glasses
10. Appropriate service manual

B. Procedure

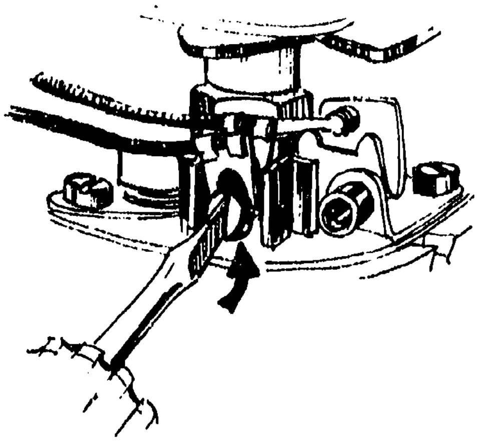
(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Make sure that ignition switch is in the off position.
2. Remove distributor cap.
3. Remove rotor.
4. Determine condition of contact points and location of wires, screws, and eccentric as used.

JOB SHEET #2

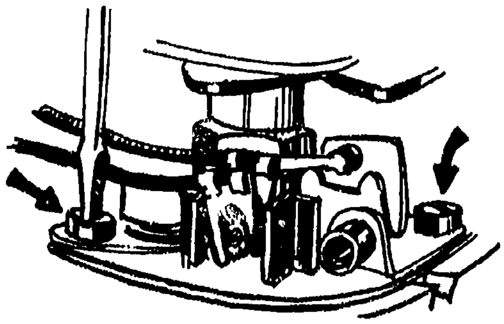
5. Disconnect contact point primary lead wire and condenser wire by loosening screw. (Figure 1)

FIGURE 1



6. Loosen screws holding contact points in place. (Figure 2)

FIGURE 2



7. Remove contact point set.

8. Remove screw holding condenser in place.

9. Remove condenser.

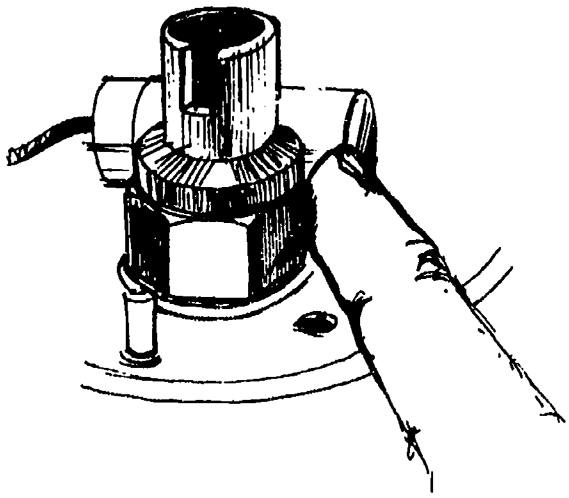
10. Clean breaker plate and distributor cam.

JOB SHEET #2

11. Lubricate distributor cam with a light coat of cam lubricant. (Figure 3)

    (NOTE: On distributors with the centrifugal weights accessible, place a drop of light oil on each weight pivot post.)

    FIGURE 3



12. Place the contact points in distributor and install attaching screws.
13. Replace condenser and attaching screw; tighten securely.
14. Replace the primary lead and condenser wires.

    (NOTE: Position the wires in such a manner to avoid binding or grounding.)

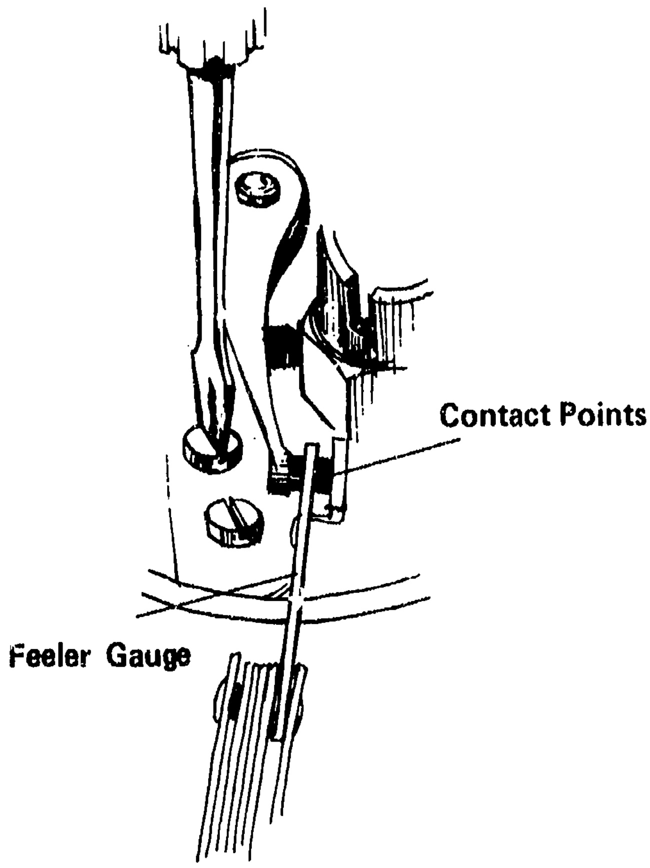
15. Tighten primary lead and condenser wires securely.
16. Check point alignment and adjust as required.
17. Check contact point breaker spring tension.

JOB SHEET #2

18. Adjust contact point opening. (Figure 4)

    (NOTE: Crank the engine to position the rubbing block of the contact points on the peak of the cam lobe.)

FIGURE 4



19. Adjust contact points to manufacturer's recommendations.

20. Tighten contact point attaching screws securely; recheck contact point opening.

21. Install rotor.

    (NOTE: Make sure the rotor is positioned correctly and securely in place.)

22. Install distributor cap.

    (NOTE: Make sure the distributor is positioned correctly and securely in place.)

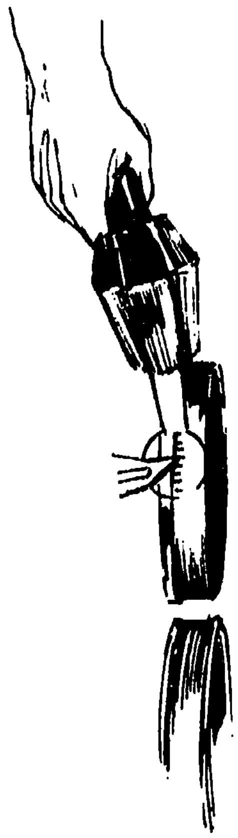
23. Replace distributor in engine, if removed.

24. Start engine.

JOB SHEET #2

25. Set timing to manufacturer's specification. (Figure 5)

FIGURE 5



IGNITION CIRCUITS
UNIT VI

JOB SHEET #3 — ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

A. Tools and materials

1. Engine
2. Dwell meter
3. Hex contact point adjusting tool
4. Safety glasses
5. Appropriate service manual

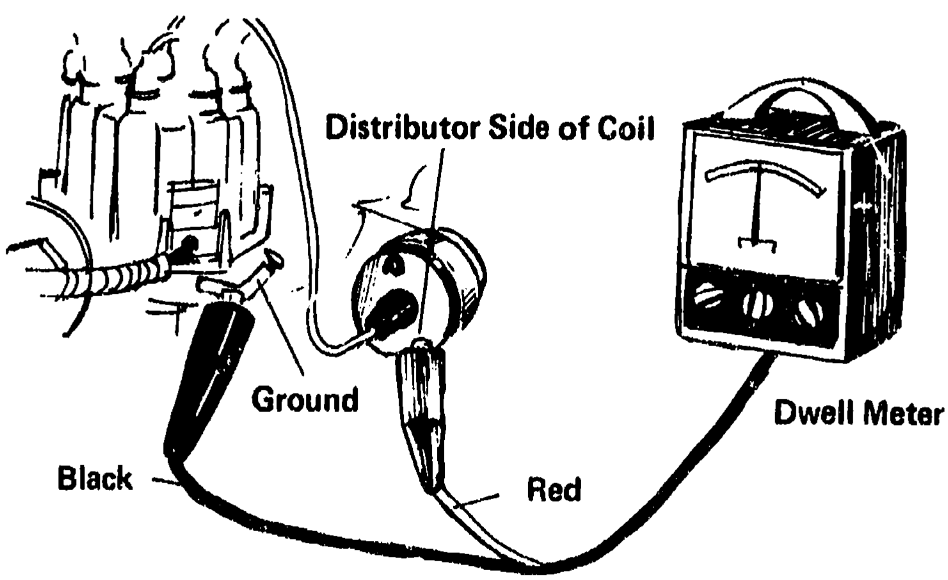
B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Connect dwell meter. (Figure 1)

   (CAUTION: Observe correct hookup procedures, and position wires away from moving engine parts.)

   FIGURE 1



2. Refer to manufacturer's specifications for desired dwell setting.
3. Start the engine.

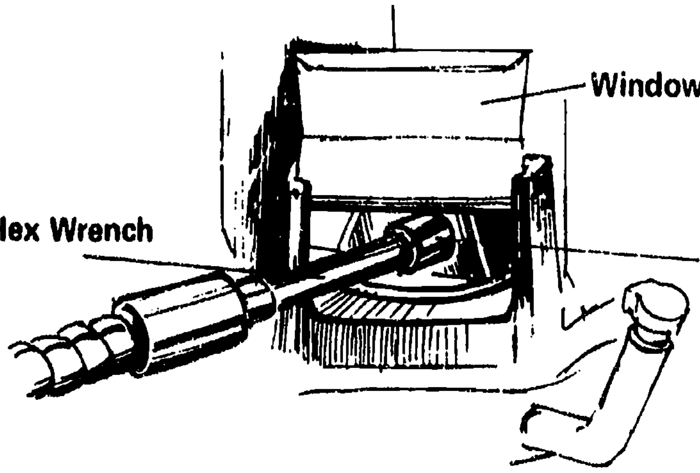
JOB SHEET #3

4. Adjust idle speed to manufacturer's specification.

5. Raise distributor cap adjustment window.

6. Insert hex wrench into contact point adjustment screw. (Figure 2)

FIGURE 2



7. Adjust contact point dwell while observing dwell meter reading to comply with manufacturer's specifications.

   (NOTE: Recheck engine idle speed.)

8. Remove hex wrench and recheck dwell reading.

9. Shut off the engine.

10. Remove dwell meter.

11. Push window on distributor cap down securely.

IGNITION CIRCUITS
UNIT VI

JOB SHEET #4 — CHECK AND SET IGNITION TIMING

A. Tools and materials

1. Engine
2. Timing light
3. Combination end wrenches, 7/16"-9/16"
4. Special distributor wrenches as required
5. Chalk
6. Shop towels
7. Safety glasses
8. Appropriate service manual

B. Procedure

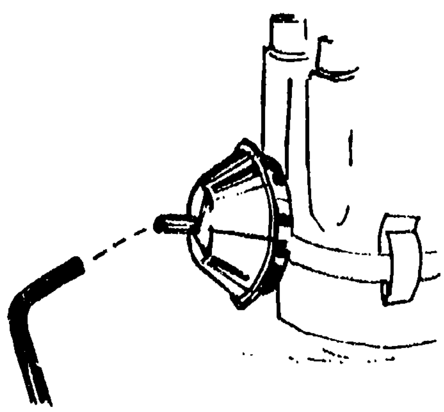
(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Obtain manufacturer's specifications for ignition timing, dwell, and rpm.

   (NOTE: Rpm and dwell must be set to manufacturer's specifications before timing is set.)

2. Remove vacuum line at the distributor and plug. (Figure 1)

   FIGURE 1



REMOVE VACUUM LINE

JOB SHEET #4

3. Locate and clean the ignition timing marks on the harmonic balancer; mark with chalk.

4. Locate and clean the timing pointer or plate on the front cover.

5. Connect the timing light according to the instructions for the light being used.

   (NOTE: Do not puncture spark plug cables with pins or clips to make connections.)

6. Position wires away from moving engine parts.

7. Start the engine.

8. Make sure the engine is idling at manufacturer's recommendations.

   (NOTE: The engine must idle correctly to prevent incorrect timing caused by the centrifugal advance.)

9. Direct the timing light toward the timing marks. (Figure 2)

   (NOTE: If the timing is correct, the timing marks will line up at the check point. If the timing is incorrect, proceed as follows.)

   FIGURE 2

JOB SHEET #4

10. Loosen the clamp or lock screw on the distributor.

11. Move the distributor until the timing marks are lined up. (Figure 3)

FIGURE 3

MOVE DISTRIBUTOR TO ADJUST TIMING

12. Tighten the clamp or lock screw on the distributor.

13. Recheck timing.

14. Shut off engine.

15. Disconnect timing light.

    (NOTE: Remove timing light adapter on spark plug if used.)

16. Replace vacuum line on distributor.

IGNITION CIRCUITS
UNIT VI

JOB SHEET #5 — REMOVE, SERVICE, AND REPLACE SPARK PLUGS

A. Tools and materials

1. Engine
2. Spark plug socket, 3/8" drive
3. Ratchet, 3/8" drive
4. Extensions, 3"-6"-10" by 3/8" drive
5. Shop towels
6. Safety glasses
7. Appropriate service manual
8. Torque wrench

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Remove spark plug wires.

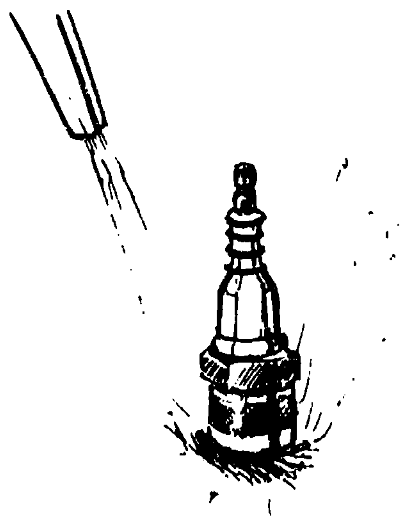
   (NOTE: Pull the wire from the spark plug by grasping the terminal, not by pulling on the wire.)

2. Loosen the spark plugs.

3. Clean the area around the spark plug by blowing, wiping, or brushing. (Figure 1)

   (CAUTION: Protect your eyes when using compressed air.)

   FIGURE 1



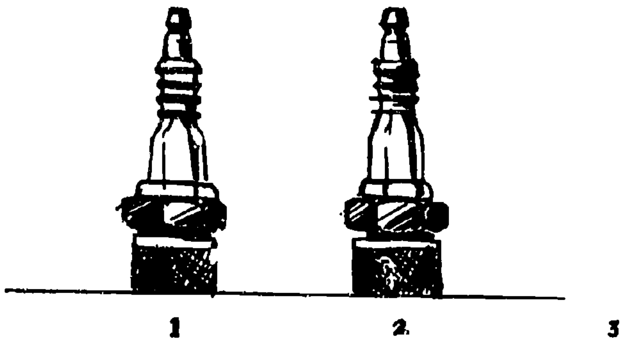
CLEAN AROUND SPARK PLUG

JOB SHEET #5

4. Remove the spark plugs.

(NOTE: Arrange the spark plugs in order as they are removed. The condition of the spark plug can tell a lot about the operation of a particular cylinder. See Figure 2.)

FIGURE 2



ARRANGE IN ORDER

5. Wipe the plug hole seat with a clean, dry cloth.

(NOTE: Be careful not to get dirt or filings into the combustion chamber.)

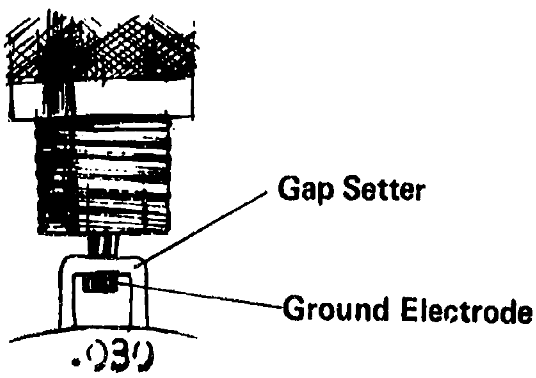
6. Consult the service manual for the proper spark plug.

7. Reset gap on new spark plugs to manufacturer's specifications. (Figure 3)

(NOTE: Use a wire gauge to check the gap. Make sure the electrode surfaces are parallel. Regap every time plugs are serviced.)

(CAUTION: Bend only the ground electrode.)

FIGURE 3



RESET SPARK PLUG GAP

JOB SHEET #5

8. Install the plug by hand until tight.

9. Finish the installation with a torque wrench, using torque recommendation in Table 1.

Table 1

SAE-ISO RECOMMENDED INSTALLATION TORQUE

Plug Thread	Cast Iron Heads		Aluminum Heads	
	Pound Feet	Newton Meters	Pound Feet	Newton Meters
10mm Gasket Seat	7-11 lb. ft.	10-15NM	7-11 lb. ft.	10-15NM
12mm Gasket Seat	11-19 lb. ft.	15-25NM	11-19 lb. ft.	15-25NM
14mm Gasket Seat	26-29 lb. ft.	35-40NM	15-22 lb. ft.	20-30NM
14mm Tapered Seat	7-15 lb. ft.	9-20NM	7-15 lb. ft.	9-20NM
18mm Gasket Seat	32-38 lb. ft.	43-52NM	28-34 lb. ft.	38-46NM
18mm Tapered Seat	15-20 lb. ft.	20-27NM	15-20 lb. ft.	20-27NM
7/8"-18	35-43 lb. ft.	47-58NM	31-39 lb. ft.	42-53NM

If no torque wrench is available — tapered seat 14 and 18mm — tighten 1/16" turn (snug) after finger tight. 14 and 18mm gasket seat plugs — tighten 1/2" turn past snug. 12mm gasket seat plugs — tighten 3/8" turn past snug. 10mm gasket seat plugs — tighten 1/4" turn past snug.

Courtesy of Allied Aftermarket, Division of Allied-Signal, Inc.

10. Replace the spark plug wires in the proper order.

    (NOTE: Push the spark plug wires securely into place, and make sure they are in the brackets or holders.)

IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #1 — REMOVE AND INSTALL A DISTRIBUTOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		YES	NO
1.	Checked out proper tools and materials.	____	____
2.	Disconnected negative battery cable.	____	____
3.	Removed the distributor wire from coil or distributor.	____	____
4.	Removed distributor cap.	____	____
5.	Removed vacuum hose and plugged.	____	____
6.	Removed clamp screw and hold-down clamp.	____	____
7.	Removed distributor.	____	____
8.	Removed number one spark plug and found top dead center on number one cylinder.	____	____
9.	Installed distributor.	____	____
10.	Installed hold-down clamp and clamp screw.	____	____
11.	Replaced vacuum line.	____	____
12.	Replaced distributor cap and wires.	____	____
13.	Replaced spark plugs and plug wires.	____	____
14.	Checked all connections for correct placement.	____	____
15.	Started engine and checked timing.	____	____
16.	Checked in/put away tools and materials.	____	____
17.	Cleaned the work area.	____	____
18.	Used proper tools correctly.	____	____
19.	Performed steps in a timely manner (___hrs. ___min. ___sec.)	____	____
20.	Practiced safety rules throughout procedure.	____	____
21.	Provided satisfactory responses to questions asked.	____	____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Steps were performed in proper sequence.				
	4	3	2	1
Engine performs correctly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked to see that the ignition switch was off.	______	______
3. Removed distributor cap.	______	______
4. Removed rotor.	______	______
5. Disconnected wires from points and condenser.	______	______
6. Removed contact point set.	______	______
7. Removed condenser.	______	______
8. Installed new points and condenser in distributor.	______	______
9. Checked point alignment and adjusted as required.	______	______
10. Adjusted contact points.	______	______
11. Installed rotor and distributor cap.	______	______
12. Started engine and checked timing.	______	______
13. Checked in/put away tools and materials.	______	______
14. Cleaned the work area.	______	______
15. Used proper tools correctly.	______	______
16. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
17. Practiced safety rules throughout procedure.	______	______
18. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Sequence of steps				
	4	3	2	1
Point alignment				
	4	3	2	1
Performance of engine				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #3 — ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Connected dwell meter.	______	______
3. Started engine and adjusted idle.	______	______
4. Adjusted point dwell.	______	______
5. Killed engine and removed dwell meter.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Sequence of steps				
	4	3	2	1
Dwell setting				
	4	3	2	1
Engine performance				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #4 — CHECK AND SET IGNITION TIMING

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Obtained manufacturer's specifications.	______	______
3.	Removed vacuum line at the distributor and plugs.	______	______
4.	Marked harmonic balancer.	______	______
5.	Connected timing light.	______	______
6.	Started engine and set idle.	______	______
7.	Set timing using timing light.	______	______
8.	Killed engine and disconnected timing light.	______	______
9.	Replaced vacuum line and ran engine.	______	______
10.	Checked in/put away tools and materials.	______	______
11.	Cleaned the work area.	______	______
12.	Used proper tools correctly.	______	______
13.	Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
14.	Practiced safety rules throughout procedure.	______	______
15.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Sequence of steps				
	4	3	2	1
Engine timing is set correctly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

IGNITION CIRCUITS
UNIT VI

PRACTICAL TEST
JOB SHEET #5 — REMOVE, SERVICE, AND REPLACE SPARK PLUGS

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed plug wires.	______	______
3. Removed spark plugs.	______	______
4. Consulted service manual.	______	______
5. Reset or checked spark plug gap.	______	______
6. Installed spark plugs.	______	______
7. Torqued plug with torque wrench.	______	______
8. Replaced spark plug wires.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Sequence of steps				
	4	3	2	1
Spark plug gap				
	4	3	2	1
Engine performance				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

IGNITION CIRCUITS
UNIT VI

NAME ____________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power	1. Coil polarity
_____b.	Marks used to synchronize the ignition circuit so that plugs will fire at the precise time	2. Condenser
_____c.	Low voltage circuit which energizes the ignition coil	3. Dwell
_____d.	High voltage circuit which produces electrical current to jump spark plug gap	4. Electronic ignition system
_____e.	Number of degrees of distributor cam rotation that the ignition points are closed	5. Electronic module
_____f.	A unit installed between the breaker points and coil to prevent arcing	6. Primary ignition circuit
_____g.	A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground	7. Secondary ignition circuit
_____h.	Ignition system using a control unit and magnetic pickup to open and close the primary circuit	8. Spark plug
_____i.	A switching device that opens and closes the ignition to primary ground circuit	9. Timing
_____j.	Provides the gap for the high voltage spark to ignite the fuel/air mixture	10. Timing marks

2. Explain the purpose of an ignition circuit.

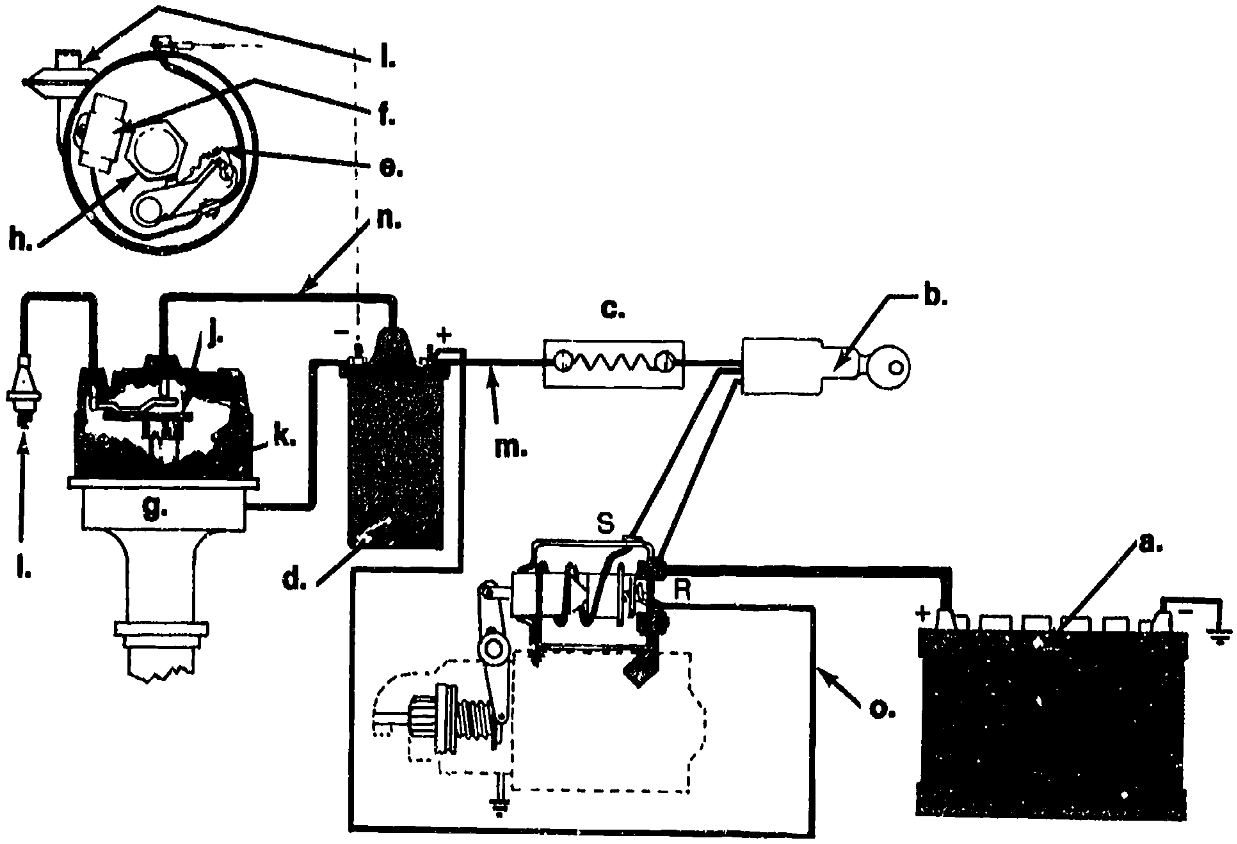
____

____

____

TEST

3. Identify the components of an ignition circuit.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________ h. ______________________

i. ______________________ j. ______________________

k. ______________________ l. ______________________

m. ______________________ n. ______________________

o. ______________________

TEST

4. Match the components of an ignition circuit on the right with their correct functions.

_____a.	Source of electrical power	1. Battery
_____b.	Opens and closes the primary circuit between battery and contact points	2. Breaker cam
_____c.	Reduces voltage in the primary circuit to protect the contact points	3. Condenser
_____d.	Transforms low voltage into high voltage necessary to jump the spark plug gap	4. Contact points
_____e.	Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs	5. Distributor
_____f.	Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow	6. Distributor cap
_____g.	Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder	7. Ignition bypass circuit
_____h.	Opens and closes the contact points	8. Ignition coil
_____i.	Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions	9. Ignition switch
_____j.	Takes the high voltage current from the coil and directs it to the correct cylinder	10. Primary ignition wire
_____k.	Holds the coil and spark plug wires in a sequence and provides a cover for the distributor	11. Primary resistance unit
_____l.	Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture	12. Rotor
_____m.	Carries low voltage from the battery through the ignition coil to the points primary side of the ignition coil	13. Secondary ignition cable
_____n.	Carries high voltage from the secondary side of the coil to the spark plug	14. Spark-advance mechanism
_____o.	Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only	15. Spark plug

TEST

5. Distinguish between primary and secondary ignition circuit components by placing a "P" next to primary components and an "S" next to secondary components.

_____a. Resistance unit

_____b. Condenser

_____c. Distributor cap

_____d. Ignition switch

_____e. Rotor

_____f. Secondary winding of the coil

_____g. High voltage wire that connects the units

_____h. Low voltage wire that connects the units

_____i. Contact points

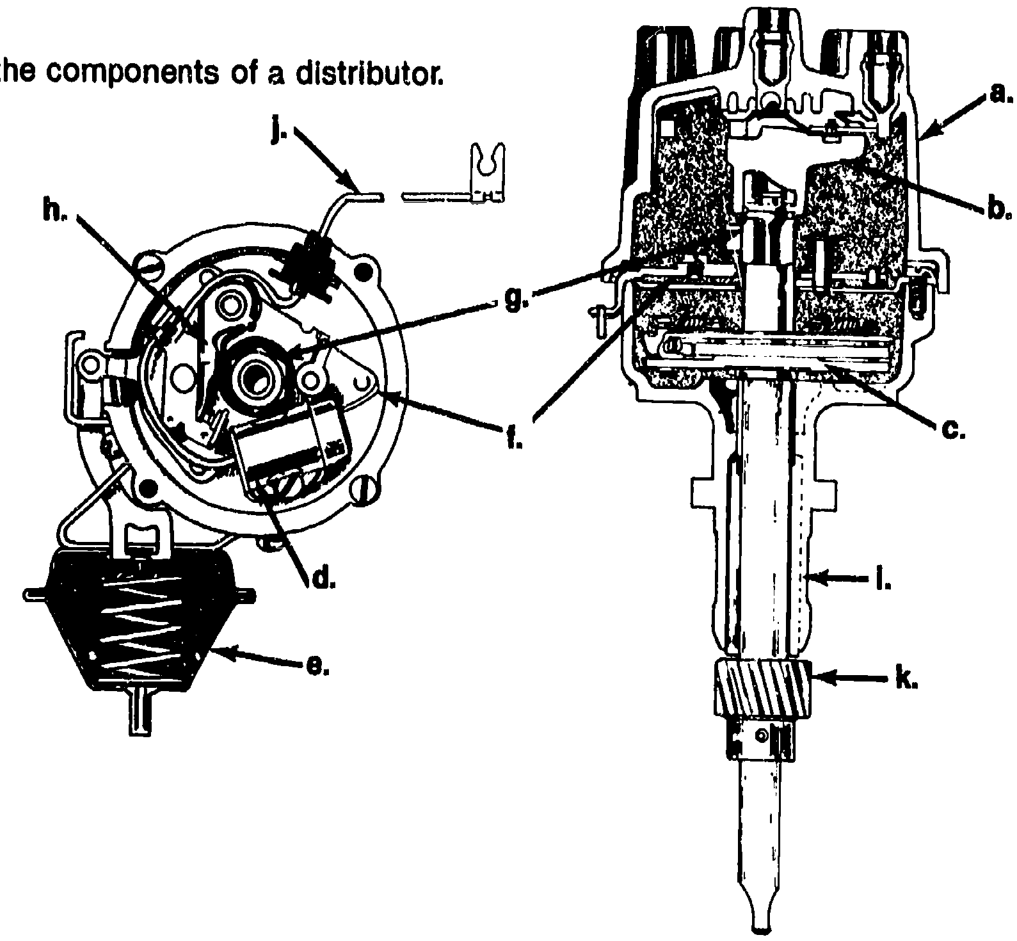
_____j. Battery

_____k. Primary winding of the coil

_____l. Spark plug

TEST

6. Identify the components of a distributor.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________ h. ______________________

i. ______________________ j. ______________________

k. ______________________

7. Arrange in order the steps in the operation of an ignition circuit beginning with the battery through one complete cycle by placing the correct sequence number beside each step.

   _____a. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current.

   _____b. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground.

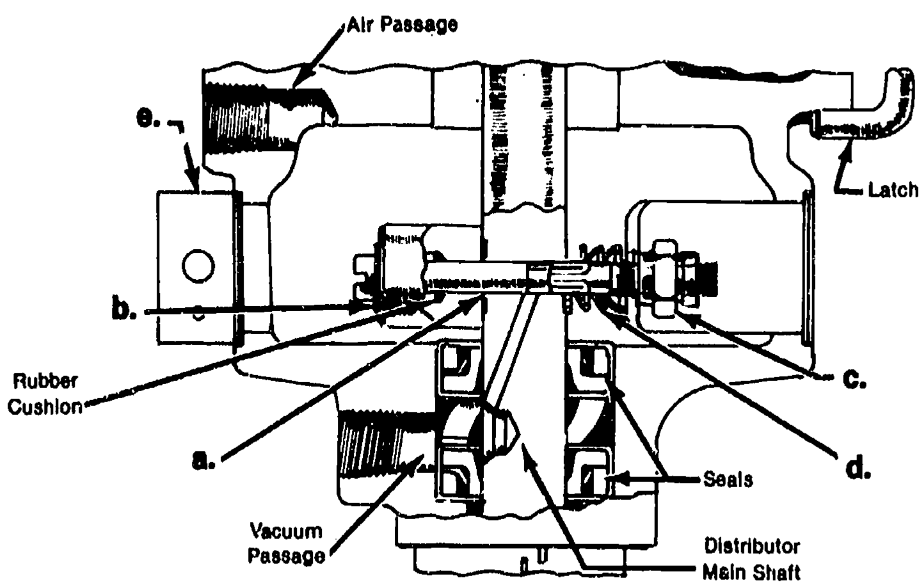
   _____c. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup.

TEST

_____d. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge.

_____e. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground.

8. Identify the components of a distributor with a built-in governor.



Built-In Engine Maximum Speed Governor Mechanism

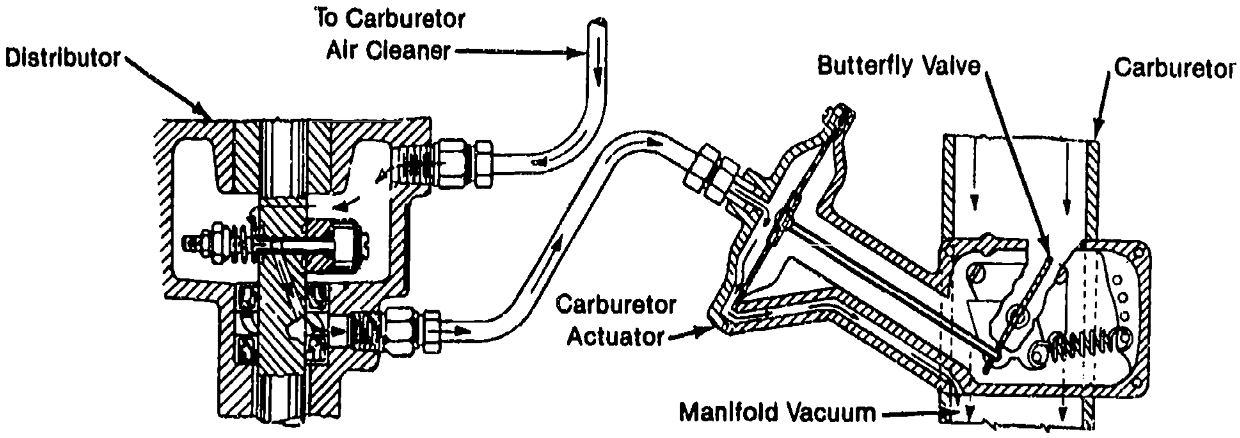
a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________

TEST

9. Arrange in order the steps in the operation of a governed distributor by placing the correct sequence number beside each step.



Air Flow And Vacuum Connections Between Carburetor And Dt co-Remy Governed Distributor (Typical)

_____a. When the distributor shaft revolves fast enough the centrifugal force of the weight pulls against the spring, causing the valve shift to move transversely in the main shaft restricting the flow of air.

_____b. When this restriction occurs, a vacuum is created in the carburetor actuator, causing it to move the butterfly valve in the carburetor, thereby governing the engine speed.

_____c. Vacuum from the intake manifold draws air through the air cleaner, through the distributor and past the carburetor actuator. An overriding feature on the butterfly valve allows the foot pedal to control the butterfly valve position except when the actuator diaphragm pull is sufficient to overcome the opposing spring force.

10. Distinguish between transistorized and capacitive discharge ignition systems by placing an "X" next to the descriptions of transistorized ignitions.

_____a. System contains special ignition distributor, amplifier, and special coil.

_____b. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil.

_____c. Amplifer is included in circuit between points and ignition coil.

_____d. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil.

TEST

11. Match major components of an electronic ignition system on the right with their functions.

_____a.	Maintains constant primary current flow according to engine speed and is bypassed during cranking	1. Armature or reluctor
		2. Control module
_____b.	Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings	3. Magnetic pickup assembly
		4 Resistor
_____c.	Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup	
_____d.	Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell	

12. Select true statements concerning general safety precautions for electronic ignition systems by placing an "X" beside each statement that is true.

_____a. Always turn the ignition off when disconnecting or connecting any electrical connectors or components.

_____b. Reverse the battery polarity or disconnect the batter with the engine running.

_____c. Disconnect the ignition switch feed wire at the distributor when making compression tests.

_____d. Check all replacement part numbers carefully.

_____e. All manufacturer's instructions must be followed carefully when using test equipment.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

    a. Remove and install a distributor. (Job Sheet #1)

    b. Remove and replace contact points and condenser. (Job Sheet #2)

    c. Adjust dwell on an externally adjustable distributor. (Job Sheet #3)

    d. Check and set ignition timing. (Job Sheet #4)

    e. Remove, service, and replace spark plugs. (Job Sheet #5)

IGNITION CIRCUITS
UNIT VI

ANSWERS TO TEST

1.

a.	9	f.	2
b.	10	g.	1
c.	6	h.	4
d.	7	i.	5
e.	3	j.	8

2. Explanation should include — The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder

3.
   a. Battery
   b. Ignition switch
   c. Primary resistance unit
   d. Ignition coil
   e. Contact points
   f. Condenser
   g. Distributor
   h. Breaker cam
   i. Spark-advance mechanism
   j. Rotor
   k. Distributor cap
   l. Spark plug
   m. Primary ignition wire
   n. Secondary ignition wire
   o. Ignition bypass circuit

4.

a.	1	f.	3	k.	6
b.	9	g.	5	l.	15
c.	11	h.	2	m.	10
d.	8	i.	14	n.	13
e.	4	j.	12	o.	7

5.

a.	P	e.	S	i.	P
b.	P	f.	S	j.	P
c.	S	g.	S	k.	P
d.	P	h.	P	l.	S

6.
   a. Distributor cap
   b. Rotor
   c. Centrifugal advance mechanism
   d. Condenser
   e. Vacuum advance unit
   f. Breaker plate
   g. Distributor cam
   h. Contact points
   i. Distributor housing
   j. Primary lead wire
   k. Distributor drive gear

ANSWERS TO TEST

7. a. 3
   b. 5
   c. 2
   d. 4
   e. 1

8. a. Valve shaft
   b. Ballast weight
   c. Adjusting nut
   d. Return spring
   e. Cover band

9. a. 2
   b. 3
   c. 1

10. b, c

11. a. 4
    b. 3
    c. 1
    d. 2

12. a, c, d, e

13. Performance skills evaluated to satisfaction of instructor

ALTERNATOR CHARGING CIRCUITS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to test charging circuits and remove, replace, and rebuild an alternator. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to alternator charging circuits with their correct definitions.
2. State the purpose of the alternator charging circuit.
3. Match alternator charging circuit components with their correct functions.
4. Identify the major parts of an alternator.
5. Discuss the construction of stator windings.
6. Distinguish between types of alternator circuits.
7. Select from a list characteristics of a brushless alternator.
8. Select true statements concerning the operation of a brushless alternator.
9. Select true statements concerning the operation of a transistorized regulator.
10. Complete statements concerning safety rules for working with alternator charging circuits.

OBJECTIVE SHEET

11. Demonstrate the ability to:

    a. Test the Ford alternator charging circuit with external regulator. (Job Sheet #1)

    b. Remove and replace an alternator. (Job Sheet #2)

    c. Disassemble, test, and reassemble an alternator. (Job Sheet #3)

    d. Test a transistorized regulator. (Job Sheet #4)

    e. Test an S.I. series alternator. (Job Sheet #5)

    f. Test charging circuit resistance for GM alternator. (Job Sheet #6)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate different types of testing equipment.
2. Have students identify different models of alternators.
3. Demonstrate the removal of different types of diodes.
4. Review safety precautions on electrical systems.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Armstrong, Ivan J. *Auto Mechanics*. Stillwater, OK: State Department of Vocational and Technical Education, 1978.

B. *Delco Remy Service Manual No. 1.2*. Service Bulletin IG-266. Detroit, MI: AC-Delco, 1983.

C. Foutes, William A. *Diesel Mechanics: Electrical Systems*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1982.

D. *Fundamentals of Service: Electrical Systems*. 4th ed. Moline, IL: Deere and Co., 1979.

E. Schulz, Erich J. *Diesel Mechanics*. 2nd ed. Dallas, TX: McGraw-Hill Book Co., 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Text**

Heavy Truck Repair Manual, Order Code D(3)
Motor Publications
555 West 57th Street
New York, NY 10019

B. **Filmstrip**

Leece-Neville 2500 VB Alternator, Order No. AS041
Educational Communications, Inc.
Department M
761 Fifth Avenue
King of Prussia, PA 19406

ALTERNATOR CHARGING CIRCUITS
UNIT VII

INFORMATION SHEET

I. **Terms and definitions**

A. Brushless alternator — An alternator that has neither slip rings nor brushes

B. Diode — Device that allows current to flow in one direction and blocks current in opposite direction

C. Grounded circuit — Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

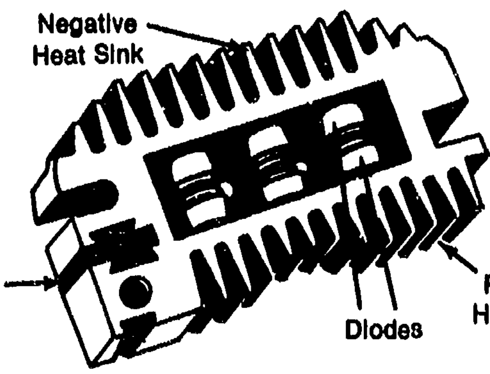
D. Heat sink — Dissipates heat from diodes

(NOTE: High ampere alternators often use finned diodes for better heat removal.)

E. Open circuit — Circuit in which a wire is broken or disconnected

F. Potentiometer — Acts as a voltage divider or voltage adjustment

G. Rectifier bridge — Six diodes mounted in one assembly



H. Rotor — Wire coil wrapped around an iron core and mounted on a rotating shaft

(NOTE: The rotor assembly does the same job for the alternator as the field coil and pole shoe do for the generator; however, the rotor assembly revolves.)

I. Short circuit — Wire touching another wire and providing a shorter path for current to flow

INFORMATION SHEET

J. Slip rings — Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

(NOTE: Current flows through the regulator, through the insulated brush, through one slip ring into the coil, and out through the other slip ring and the other brush to ground.)

K. Stator — Laminated soft iron ring with three groups of coils

(NOTE: The stator assembly does the same job as the armature in a generator; however, the stator is fixed while the armature turns.)

L. Transistorized regulator — Fully electronic unit composed of resistors, diodes, zener diode, transistors, and thermistor

II. **Purpose of the alternator charging circuit** — The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment.

III. **Alternator charging circuit components and functions** (Transparency 1)

A. Battery

1. Starts the circuit by supplying spark to start engine.
2. Helps out during peak operation when electrical load is too much for alternator.
3. Stabilizes system voltage

B. Alternator

1. Supplies electrical power to accessory circuits
2. Recharges battery

C. Regulator — Limits the alternator voltage to a safe, preset value

D. Ammeter — Measures the rate of current flow

E. Voltmeter — Indicates produced voltage

F. Indicator lights — Indicates problems in system; used in place of a meter

INFORMATION SHEET

IV. **Major parts of an alternator** (Transparencies 2 and 3)

A. Drive end frame

B. Rotor assembly

C. Stator assembly

D. Slip ring end frame

E. Diodes

F. Brush assembly

G. Pulley

V. **Construction of stator windings** — Windings have three phases which are connected together to form a "Y" or delta connection, with each winding connected to a positive and negative diode. (Transparency 4)

VI. **Types of alternator circuits**

(NOTE: The regulator places a resistance in the field circuit which reduces current flow to the alternator rotor.)

A. External regulator — Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a "B" circuit.

B. Internal regulator — Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an "A" circuit.

VII. **Characteristics of a brushless alternator** (Transparency 5)

A. High mileage unit

B. Used on both gasoline and diesel engines

C. Regulator compartment can be vented for increased capability

D. Uses large bearings at both ends

E. Has extra large grease reservoirs

F. Has extra large lip seal to keep grease in and dirt out

G. Regulator compartment is air tight

H. Designed to operate between engine overhauls without attention

INFORMATION SHEET

VIII. **Operation of a brushless alternator**

A. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.

B. The field coil is mounted to the end frame.

C. The rotor is mounted on bearings and fits between the stator and field coil.

D. The field coil produces a north pole at the right hand side of the coil.

E. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.

F. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.

G. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings.

IX. **Operation of a transistorized regulator**

A. Allows battery current to excite the alternator field coils

B. Controls charging voltage at safe values during operation by regulating the field current

X. **Safety rules for working with alternator charging circuits**

A. Never attempt to polarize the circuit.

B. Be sure the battery is in good operating condition before making any tests or adjustments.

C. Never operate the alternator in an open circuit, except when instructed in the technical manual.

D. Never short or ground the alternator terminals.

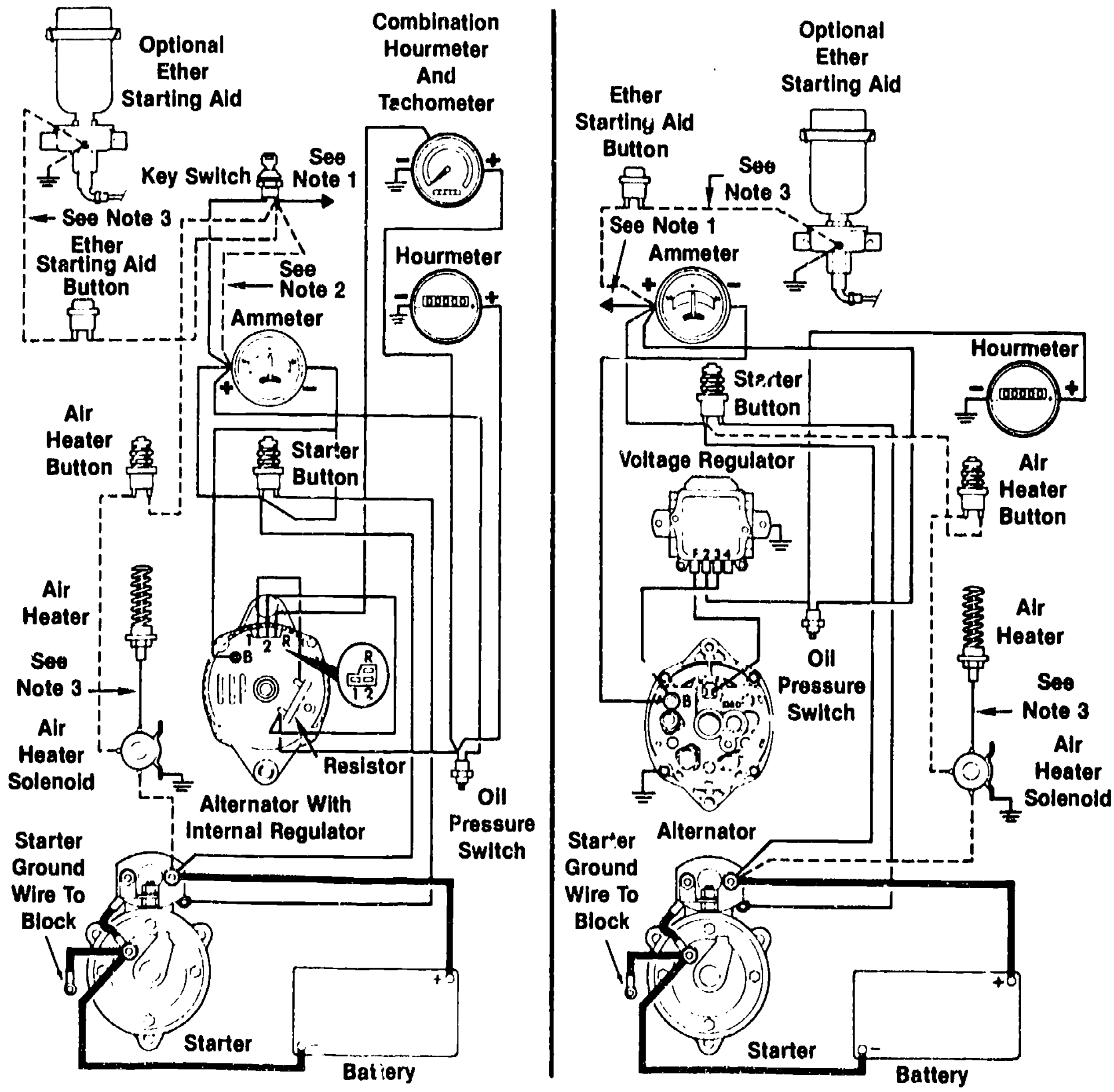
E. Do not disconnect the voltage regulator while the alternator is running.

F. Disconnect the negative battery cable first when removing the alternator or battery.

G. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder.

H. Never immerse the circuit components in cleaning solution.

Alternator Charging Circuit Components

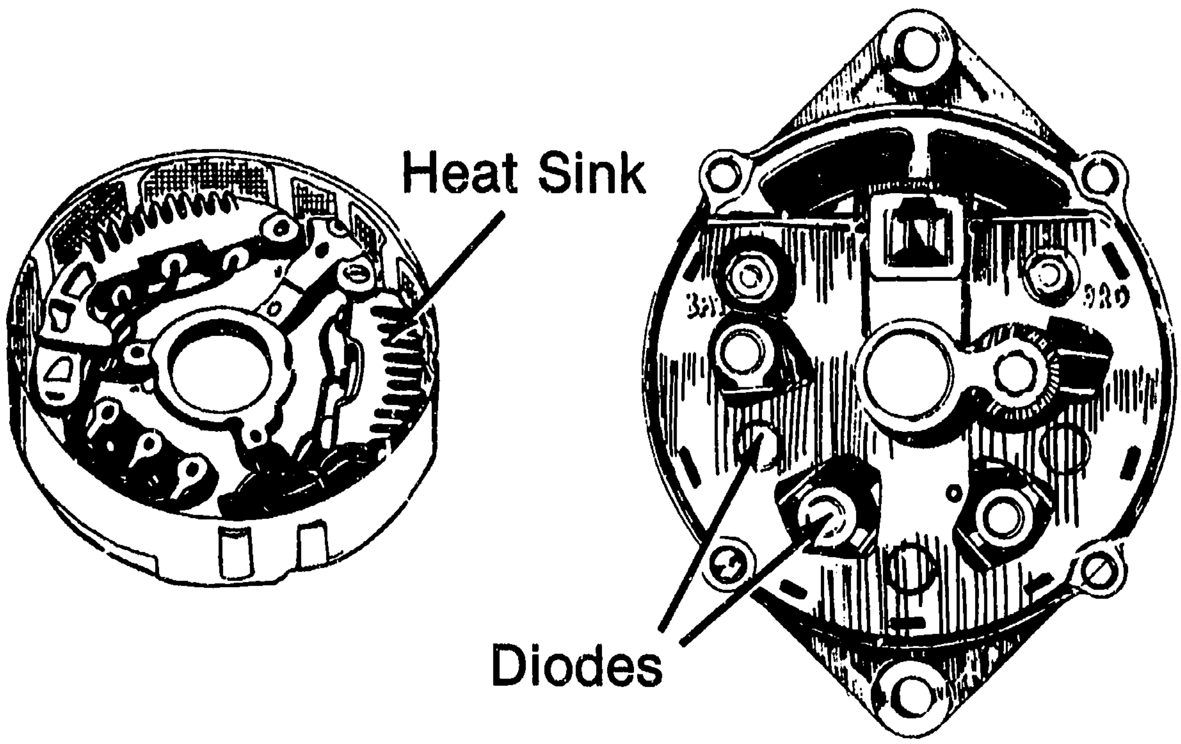


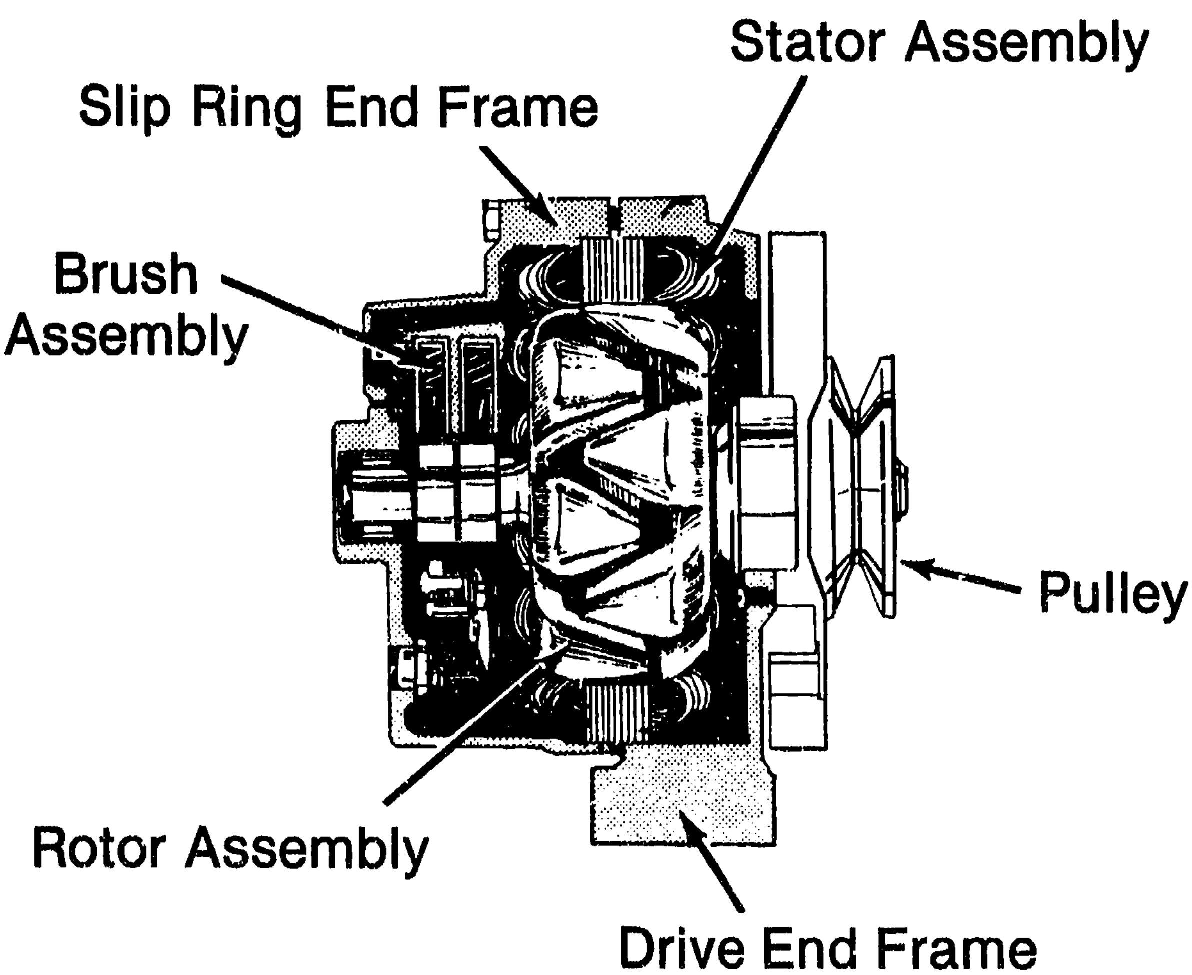
Alternator With Internal Voltage Regulator

Alternator With External Mounted Voltage Regulator

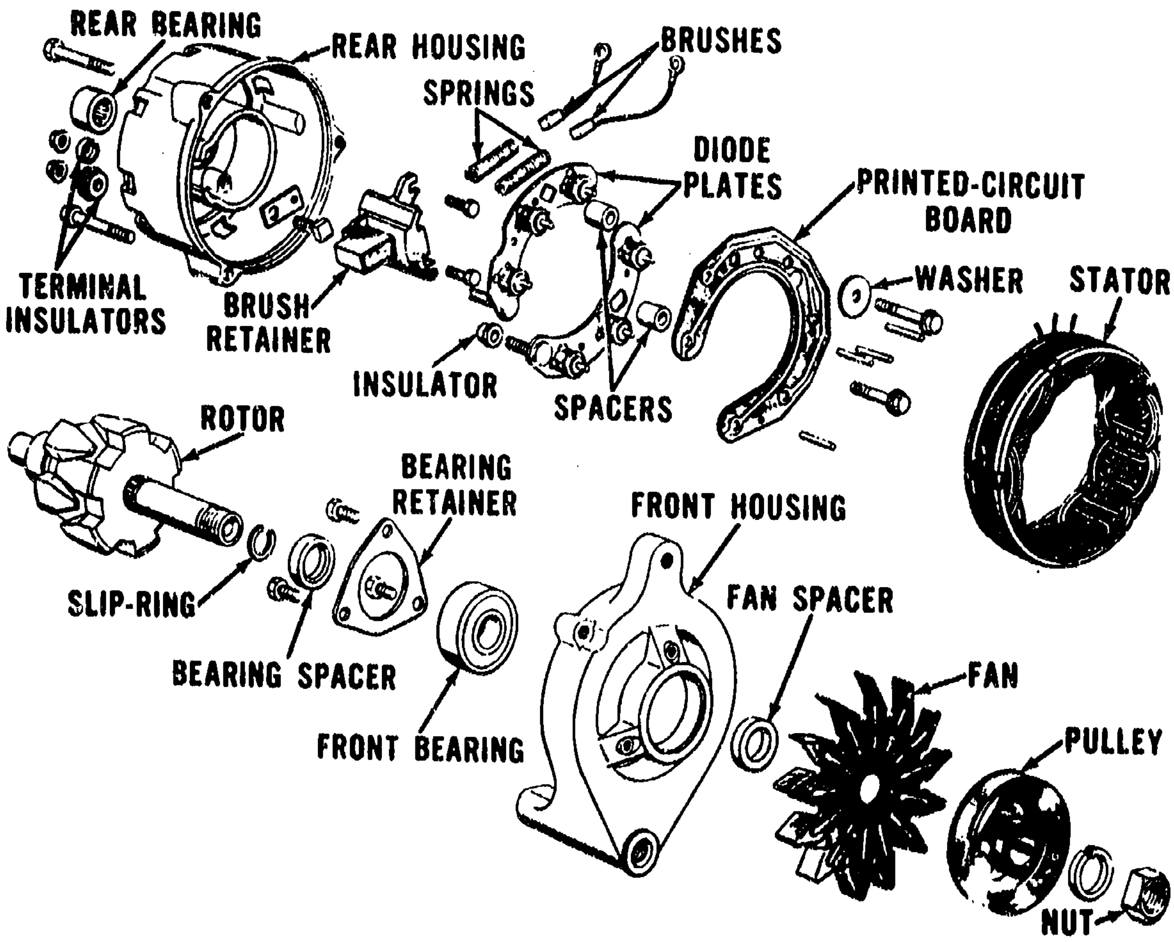
Courtesy of Deutz-Allis Corporation.

Parts of an Alternator



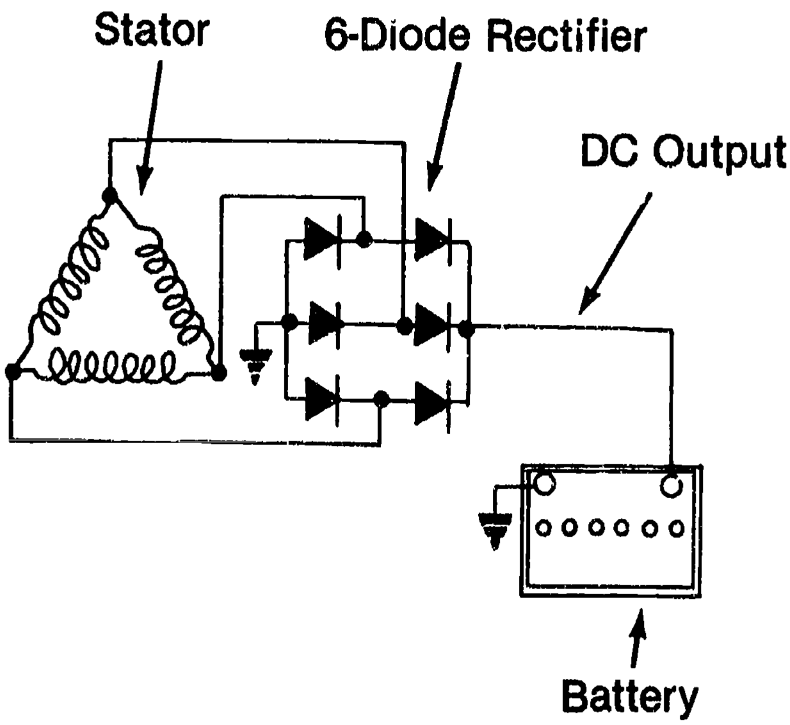


Parts of an Alternator
(Continued)

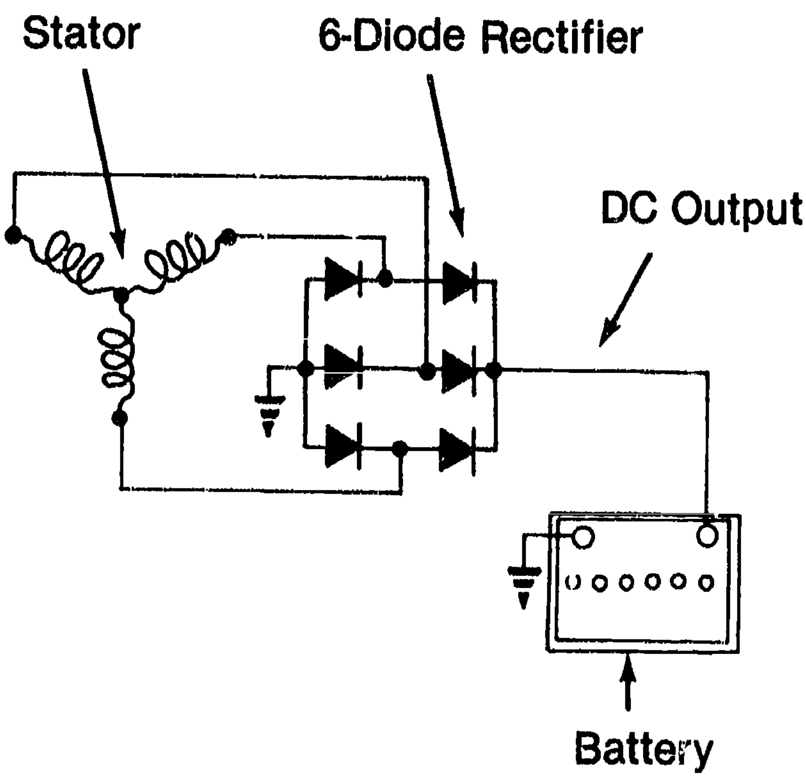


Courtesy of Ford Motor Company.

Stator Winding Construction

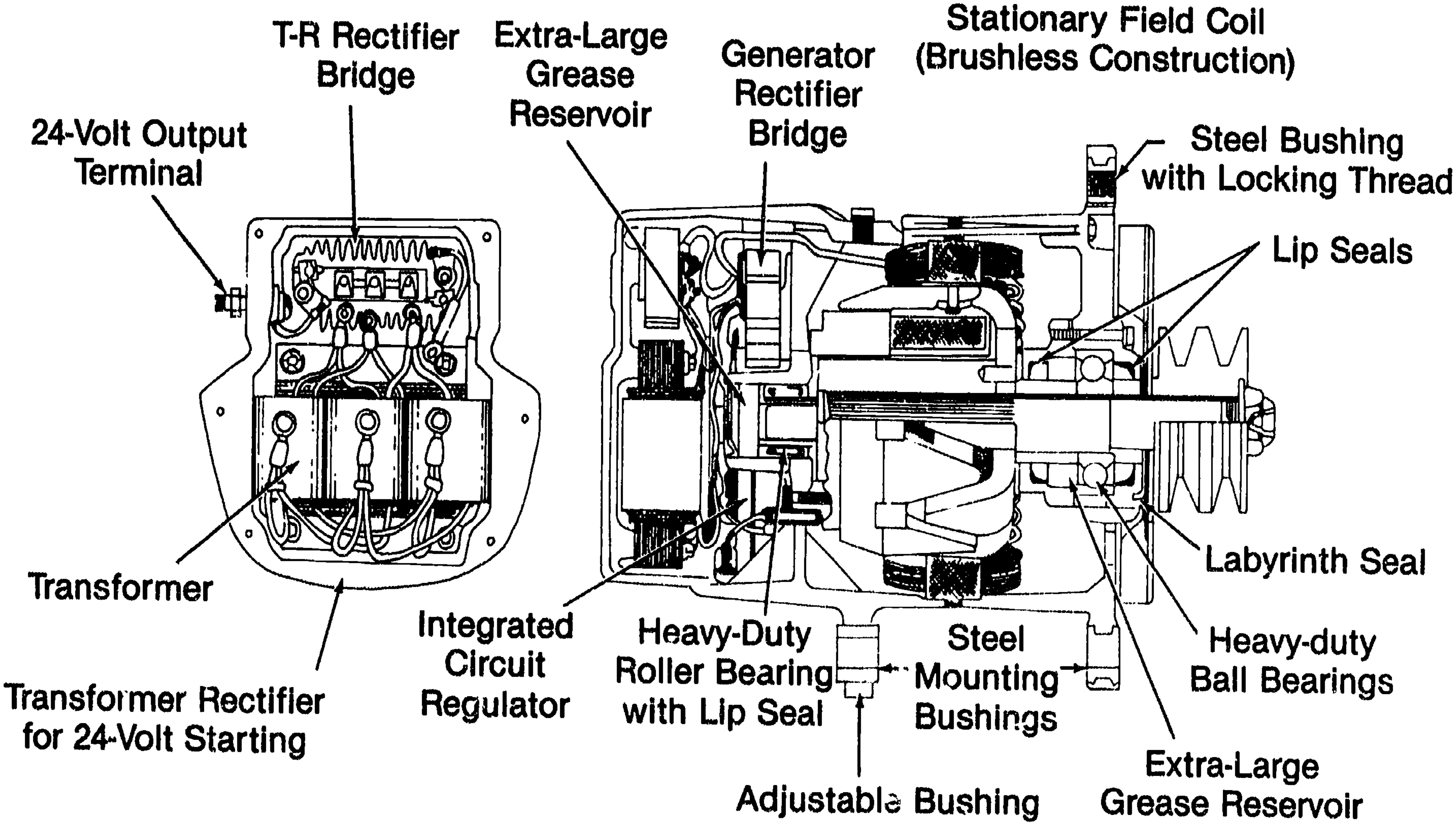


Delta-Connected Stator Windings



"Y"-Connected Stator Windings

Brushless Alternator Construction



ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #1 — TEST THE FORD ALTERNATOR CHARGING CIRCUIT WITH EXTERNAL REGULATOR

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Voltmeter
4. Ammeter
5. Variable resistor
6. Jumper wire
7. Safety glasses

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

(NOTE: There are many methods of testing the alternator systems. The method outlined in this job sheet is simplified and adaptable to most light-duty alternators.)

1. Test the battery.

   (NOTE: For valid tests, the battery must be at least half charged and in good condition.)

2. Check and adjust belt tension.

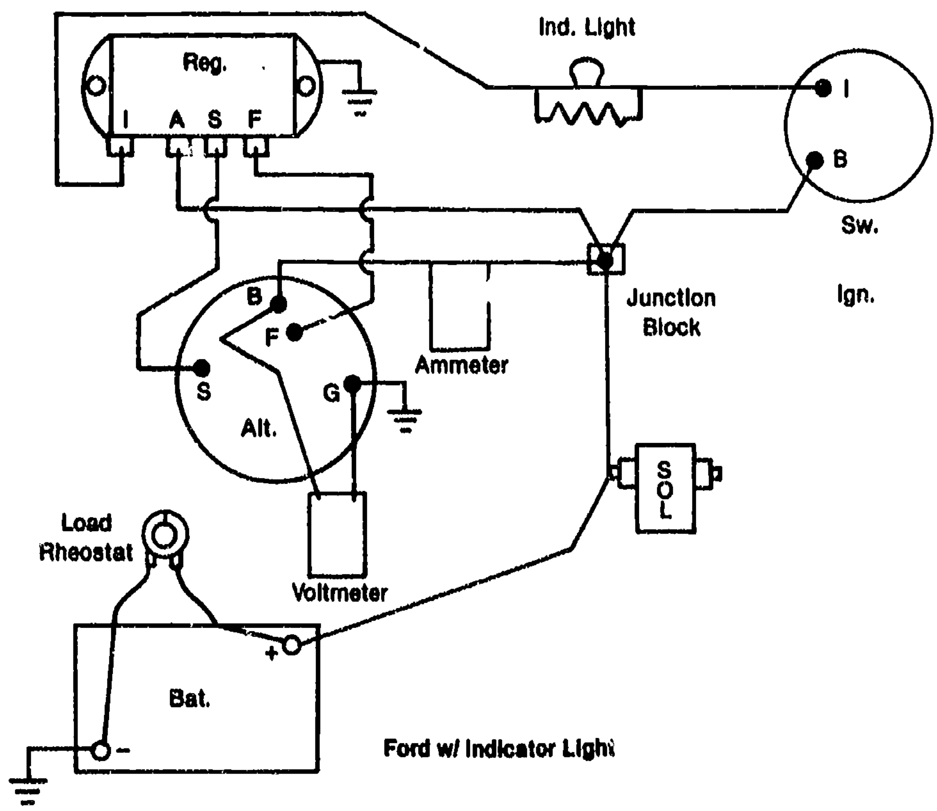
JOB SHEET #1

3. Test alternator output.

   (NOTE: The following diagnostic procedures are for a charging system that is not charging.)

   a. Make test instruments connections as shown in Figure 1.

      FIGURE 1



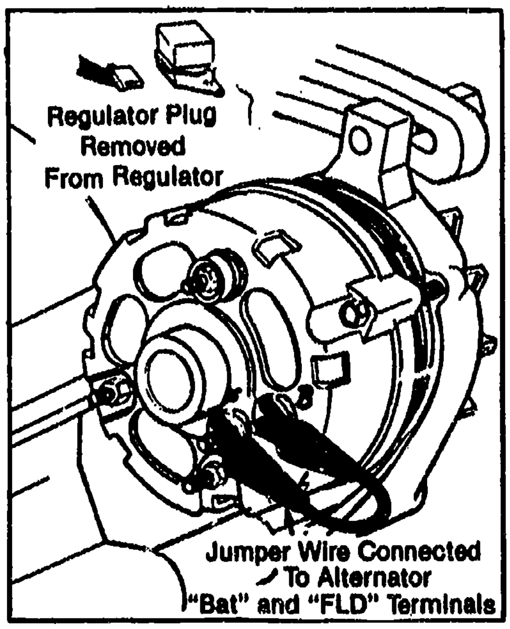
   b. Disconnect the field from the regulator by removing the regulator gang plug.

JOB SHEET #1

c. Connect the field to the battery output terminal with jumper lead. (Figure 2)

(NOTE: This "feeds" the field directly, bypassing the regulator and wiring.)

FIGURE 2



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d. Start and operate the engine at idle speed.

e. Adjust rheostat and engine speed until a speed of 2,000 rpm and a voltmeter reading of 15 volts is obtained.

(NOTE: These specifications may vary slightly from model to model; consult the appropriate service manual for accurate specifications.)

(CAUTION: Never allow voltmeter to read over 16 volts; damage to the charging system could occur.)

f. Read ammeter.

(NOTE: If the alternator starts to charge and is within 10 amps of rated output, the regulator or wiring is at fault. If the alternator does not charge, it is defective.)

g. Reduce engine speed and turn off carbon pile rheostat after current output test is completed.

h. Turn off ignition switch.

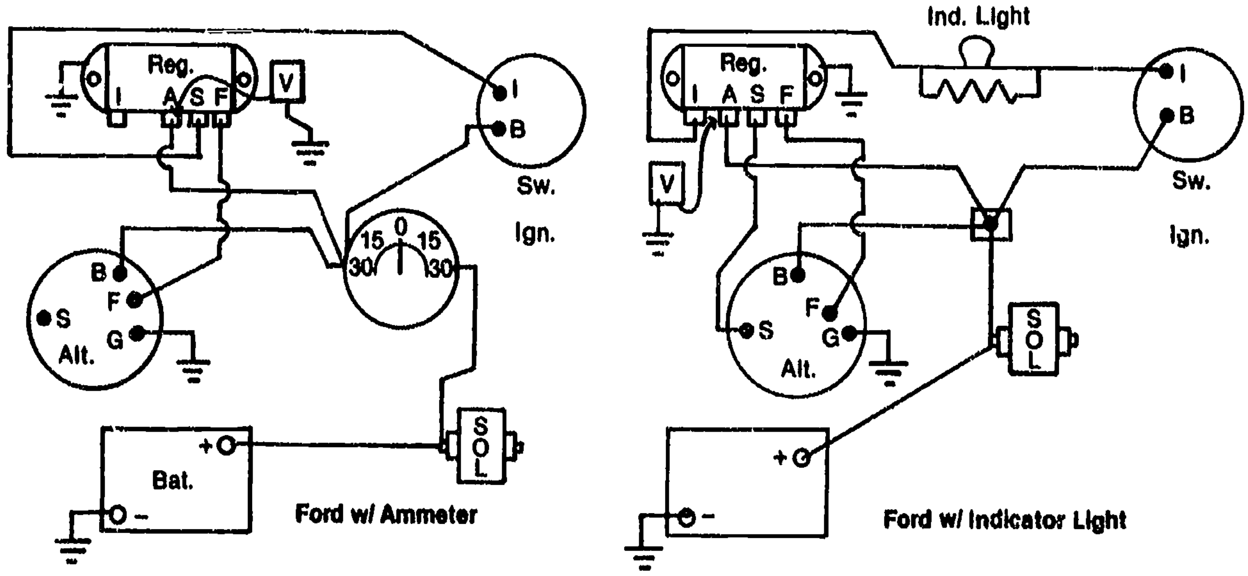
JOB SHEET #1

4. Test wiring.

   a. Hook voltmeter to the wire connecting to the "A" terminal of the regulator and observe voltmeter reading. (Figure 3)

      (NOTE: Remove gang plug from regulator.)

      FIGURE 3



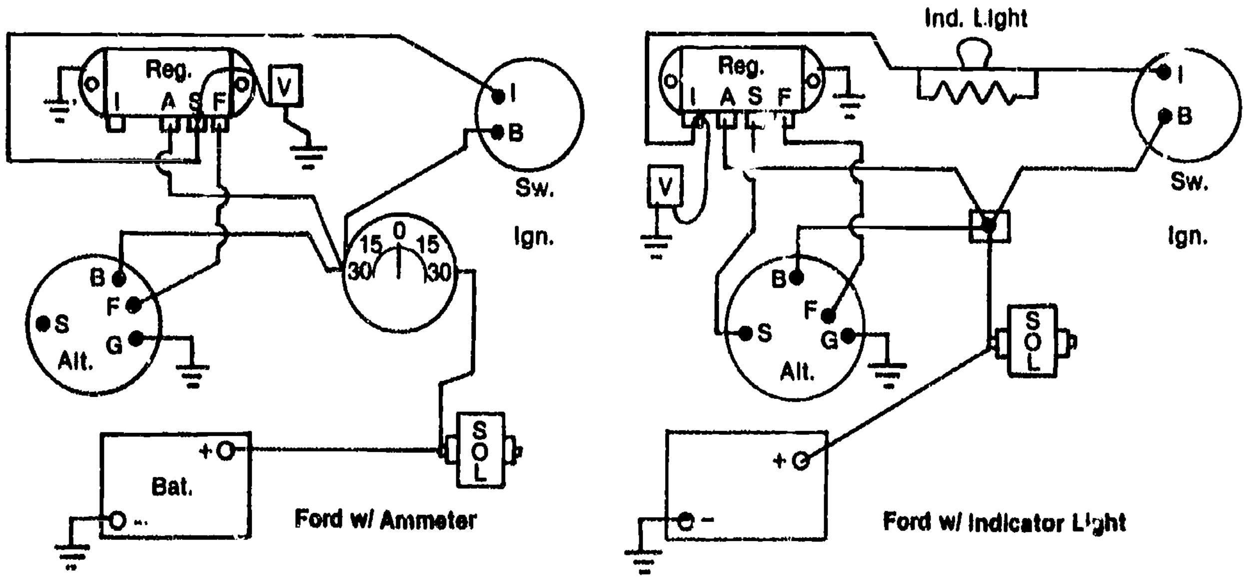
      (NOTE: If there is no voltage, repair or replace wire.)

   b. Turn on ignition switch, and check voltage of the wire leading from the ignition switch to the regulator.

      1) Test systems that have an ammeter by connecting voltmeter to the wire leading to the "S" terminal of the regulator. (Figure 4)

         (NOTE: If there is no voltage, repair or replace wire.)

         FIGURE 4



JOB SHEET #1

2) Test systems that have an indicator light by hooking voltmeter to the wire connecting to the "I" terminal of the regulator. (Figure 4)

(NOTE: If there is no voltage, repair or replace wire.)

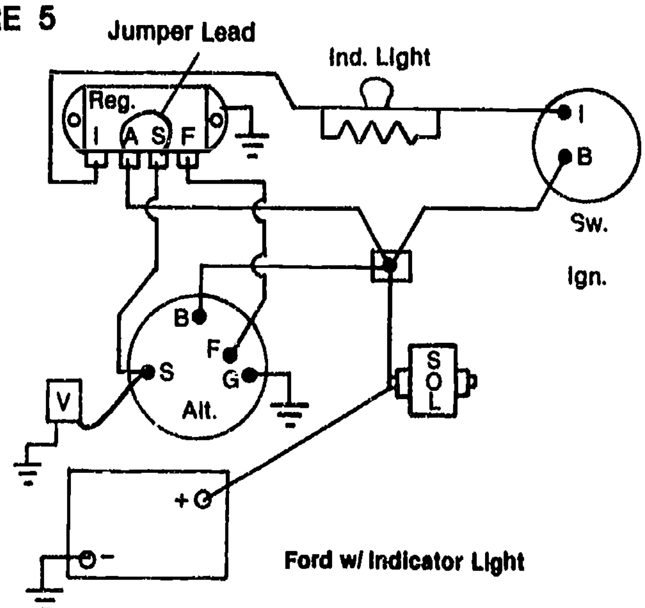
c. Turn ignition switch off.

d. Test the wire connecting the "S" terminal of the alternator to the "S" terminal of the regulator. (Figure 5)

(NOTE: This procedure is for systems with an indicator light.)

1) Connect voltmeter to the wire leading to the "S" terminal of the alternator. (Figure 5)

FIGURE 5



2) Connect jumper lead to "A" and "S" terminals of the regulator. (Figure 5)

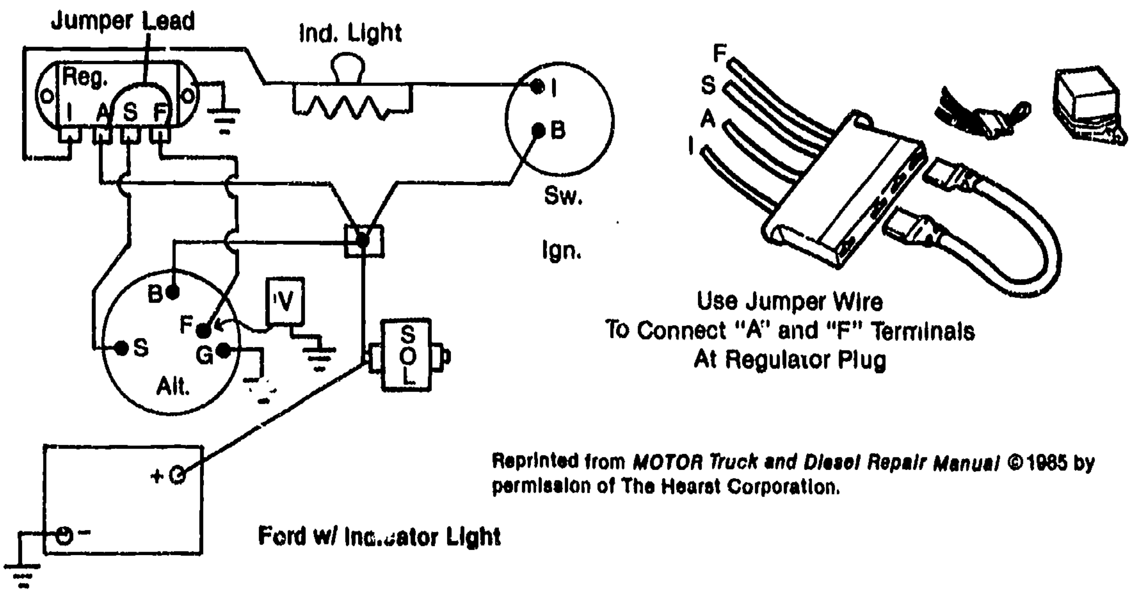
(NOTE: If there is no voltage, repair or replace wire.)

JOB SHEET #1

e. Test wire connecting the "F" terminal of the alternator to the "F" terminal of the regulator.

1) Hook voltmeter to wire leading to the "F" terminal of the alternator. (Figure 6)

FIGURE 6



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Ford w/ Indicator Light

2) Use jumper lead to connect the "A" and "F" terminals of the regulator.

(NOTE: If there is no voltage, repair or replace wire.)

f. Reconnect all regulator and alternator connections.

5. Test regulator.

a. Turn on ignition switch.

b. Check for good grounding of voltage regulator.

(NOTE: If the ground of the regulator is in question, connect jumper wire from the base of the regulator to the frame of the alternator.)

c. Connect voltmeter to the field of the alternator.

(NOTE: If there is no voltage and all the above tests were satisfactory, the voltage regulator is at fault.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #2 — REMOVE AND REPLACE AN ALTERNATOR

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Battery cable clamp removal tool
4. Shop towels
5. Safety glasses
6. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Remove alternator.

   a. Remove battery ground.

   b. Remove wire leads.

   (NOTE: Alternator leads should be tagged for replacement.)

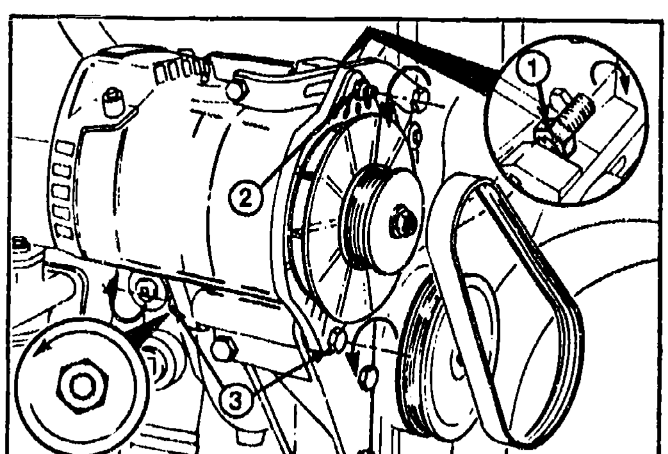
   c. Loosen the adjusting screw locknut. (Figure 1)

   d. Loosen retaining nut. (Figure 1)

   e. Loosen mounting bolts. (Figure 1)

   f. Remove alternator belt.

FIGURE 1



Courtesy of Cummins Engine Co., Inc.

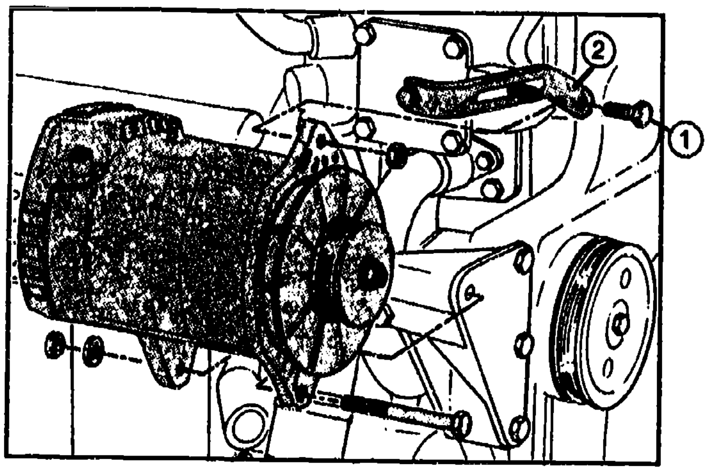
JOB SHEET #2

g. Remove the adjusting link mounting bolt and the adjusting link. (Figure 2)

h. Remove the alternator mounting capscrew, nut, washer, and the alternator. (Figure 2)

FIGURE 2

1. Adjusting Link Mounting Bolt
2. Adjusting Link



Courtesy of Cummins Engine Co., Inc.

2. Install alternator.

   a. Install the alternator, capscrew, washer, and nut to the mounting bracket.

      (NOTE: Do not tighten the capscrew and nut until the alternator belt is installed and adjusted.)

   b. Install the adjusting link and mounting capsc.ew.

   c. Install and adjust the alternator belt, using co.rect belt tension gauge.

   d. Install wire leads and tighten securely.

   e. Install battery ground cable.

3. Start engine and check operation of alternator.

ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #3 — DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

A. Tools and materials

1. Alternator
2. Basic hand tool set
3. Alternator pulley removal tools
4. Alternator diode removal equipment
5. Alternator testing equipment
6. Torque wrench
7. Shop towels
8. Safety glasses
9. Appropriate service manual

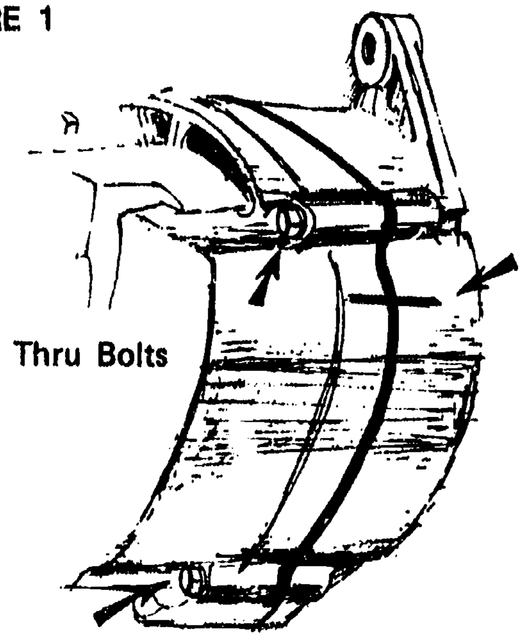
B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Disassemble alternator.

   a. Scribe the alternator before disassembly. (Figure 1)

FIGURE 1



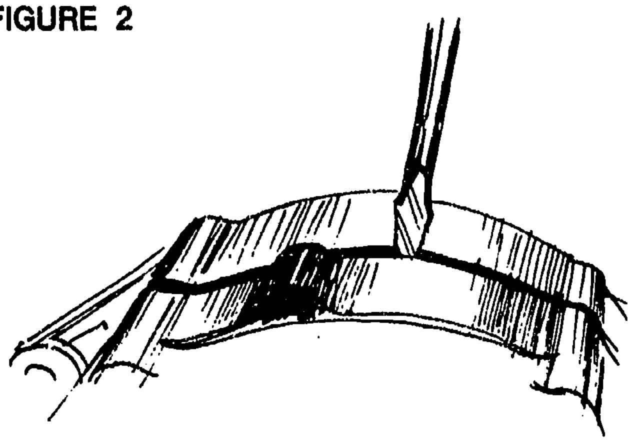
JOB SHEET #3

b. Remove through bolts holding the end frames together.

c. Pry at bolt locations to separate the drive end frame from the slip ring end frame. (Figure 2)

(NOTE: Be sure stator stays with slip ring end of frame.)

FIGURE 2



d. Remove the slip ring end frame and stator (as an assembly) from drive end frame and rotor assembly.

e. Remove the three stator lead attaching nuts.

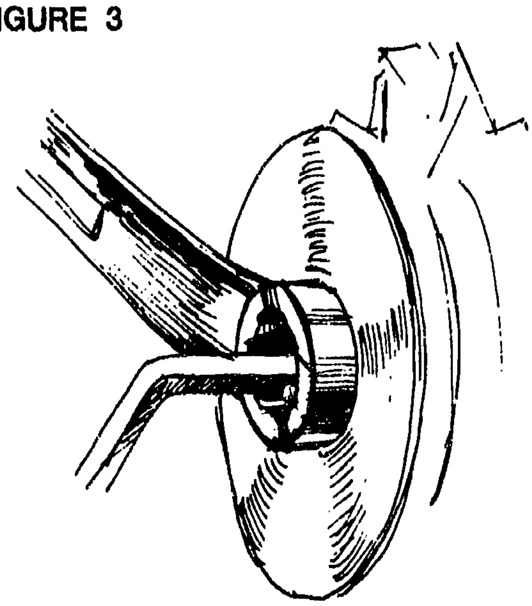
f. Separate stator from slip ring end frame.

g. Remove screws, brushes, and brushholder assembly.

h. Remove heat sink from end frame.

i. Remove pulley retaining nut. (Figure 3)

FIGURE 3



REMOVE PULLEY RETAINING NUT

JOB SHEET #3

j. Remove pulley and fan using pullers as required.

k. Remove rotor and spacers from end frame assembly.

l. Remove drive frame bearing retainer and bearing from drive end frame.

2. Test alternator components.

   a. Wash all metal parts except stator, diode, and rotor assemblies.

   b. Replace bearings as required.

   c. Inspect rotor slip rings.

   (NOTE: The slip rings should be clean and free of scratches.)

   d. Service as required.

   e. Inspect brushes for wear.

   f. Replace brushes as required.

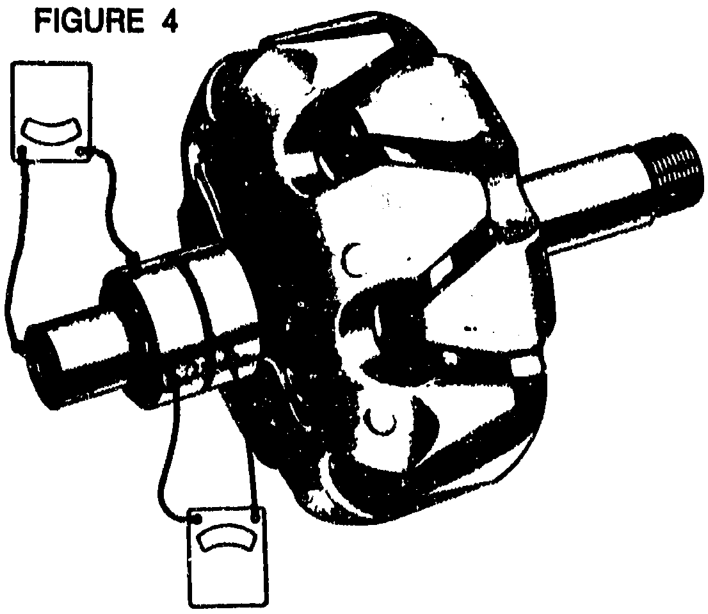
   g. Test the rotor for grounds. (Figure 4)

      1) Hold one test probe of the ohmmeter against the rotor shaft.

      2) Hold the other against either of the slip rings. (Figure 4)

      (NOTE: If the field coil is not grounded, the ohmmeter will not move from its infinite position.)

FIGURE 4



Ohmmeter

Checking Rotor for Grounds, Shorts and Opens

Reprinted with permission of Delco Remy Division, GM Corp.

JOB SHEET #3

h. Test rotor for an open or short circuit by holding one probe against each slip ring. (Figure 4)

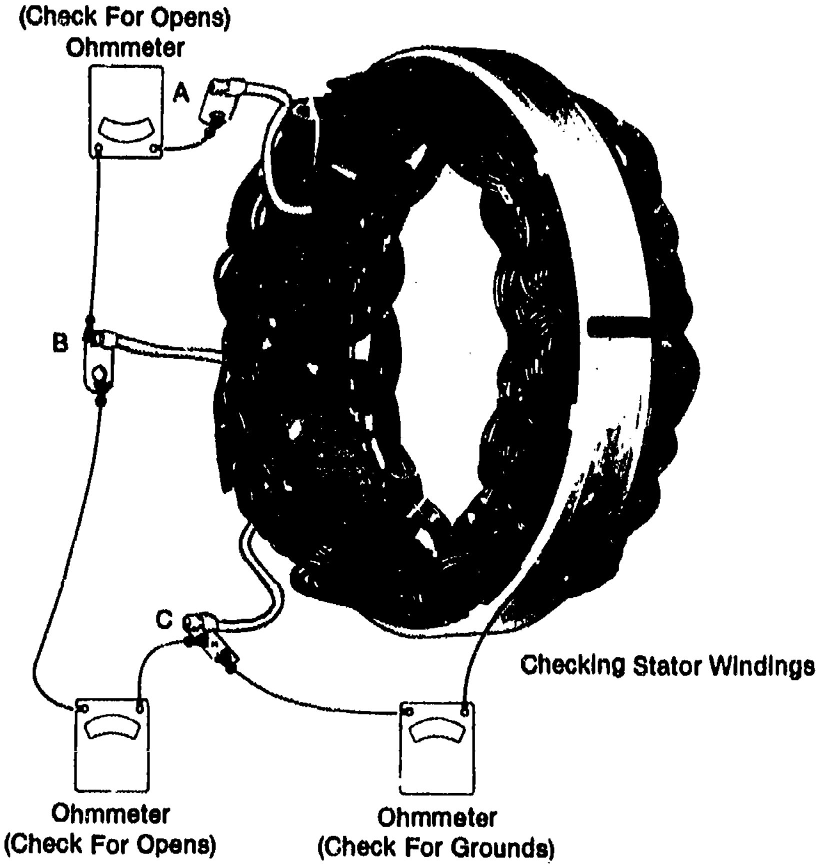
(NOTE: If there is no open or short circuit, the ohmmeter should indicate the resistance specified in the service manual.)

i. Test the stator for grounds.

1) Connect one test probe of the ohmmeter to the stator frame.

2) Connect the other test probe to any stator lead. (Figure 5)

FIGURE 5



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(NOTE: The ohmmeter will show an infinity reading when the stator winding is not grounded.)

j. Test the stator for open circuit.

(NOTE: This test will not work on a delta wound stator.)

1) Connect test probes of an ohmmeter between A and B stator leads. (Figure 5)

JOB SHEET #3

2) Connect test probes between A and C stator leads. (Figure 5)

3) Connect tests probes between B and C stator leads. (Figure 5)

(NOTE: If the ohmmeter fails to show continuity, there is an open winding.)

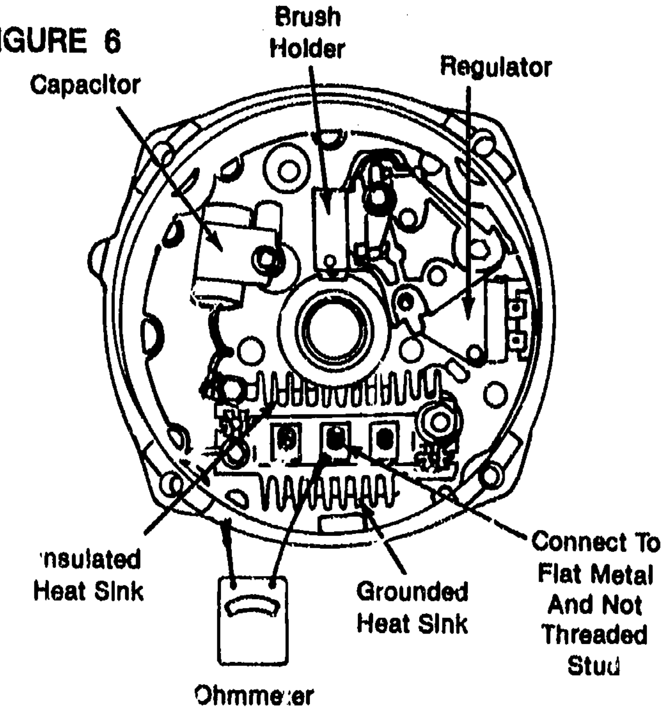
k. Test diodes for shorts or opens.

(NOTE: If a test lamp is used instead of an ohmmeter, voltage should be 12 volts or less.)

1) Connect one of the ohmmeter leads to the heat sink or diode body. (Figure 6)

2) Connect the other ohmmeter lead to the diode lead or flat metal connector. (Figure 6)

FIGURE 6



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JOB SHEET #3

3) Observe the ohmmeter reading.

(NOTE: If both readings are low, the diode is shorted. If both are high, the diode has an open. If one reading is high and the other is low, the diode is good.)

4) Check the other diodes in the same manner.

5) Replace any defective diodes.

(NOTE: Use special tools manufactured for this purpose.)

I. Test diode trio for resistance reaction.

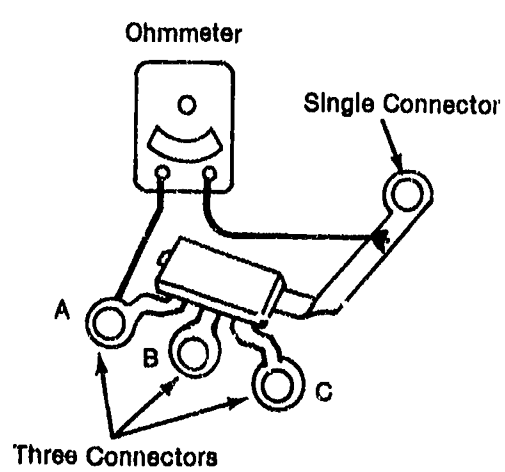
(NOTE: A diode trio is used in conjunction with an integrated voltage regulator.)

1) Connect the negative ohmmeter probe to the long lead.

2) Connect the positive probe to each short lead. (Figure 7)

(NOTE: You should obtain at each short lead a low-resistance reaction.)

FIGURE 7



JOB SHEET #3

3) Reverse the ohmmeter probes. (Figure 7)

(NOTE: You should obtain a high reading.)

3. Reassemble alternator.

   a. Assemble heat sink to end frame.

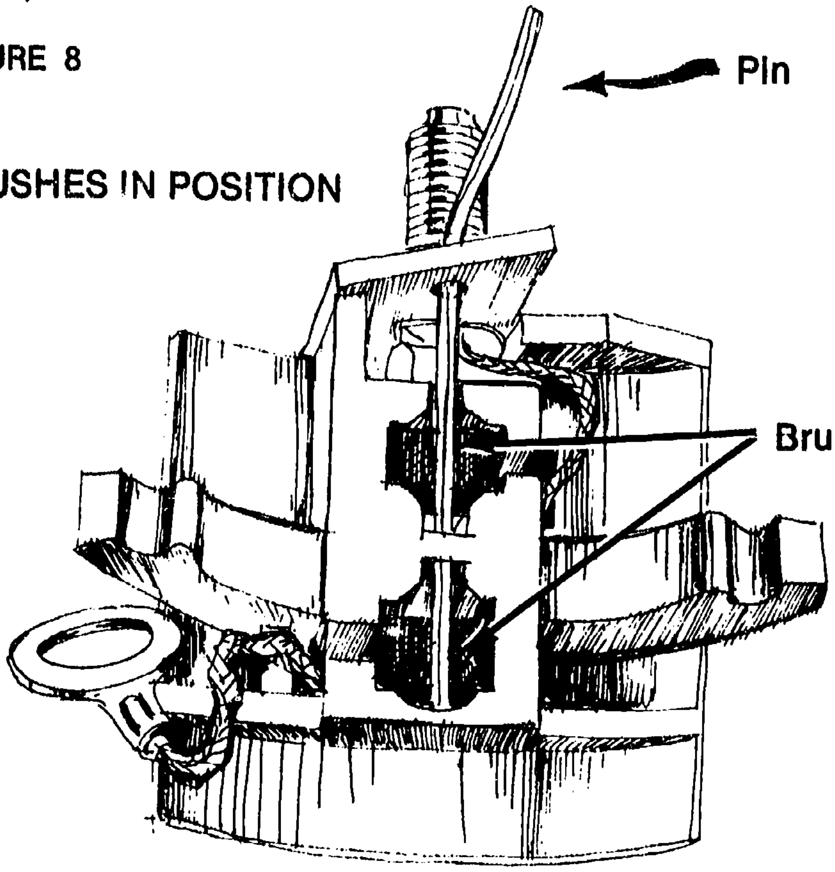
JOB SHEET #3

b. Install brush holder and brushes into slip ring end frame. (Figure 8)

(NOTE: Insert a pin or wire through the hole to hold the brushes in the holder.)

FIGURE 8

BRUSHES IN POSITION



c. Install stator assembly in slip ring end frame, and locate diode connectors over the relay, diode, and stator leads.

d. Install and tighten terminal nuts securely.

e. Install bearing in drive end frame.

f. Install rotor in drive end frame.

g. Install fan, spacer, pulley, and retaining nut.

h. Tighten nut to manufacturer's specifications.

i. Assemble slip ring, end frame, and stator assembly to drive end frame and rotor assembly.

(NOTE: Align end frames by referring to scribe marks put on during disassembly.)

JOB SHEET #3

j. Install through bolts in the end frame assembly.

k. Tighten bolts securely.

l. Remove wire holding brushes in place.

m. Check alternator operation.

ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #4 — TEST A TRANSISTORIZED REGULATOR

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Voltmeter
4. Carbon pile resistor
5. Ammeter
6. Jumper wire
7. Safety glasses
8. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

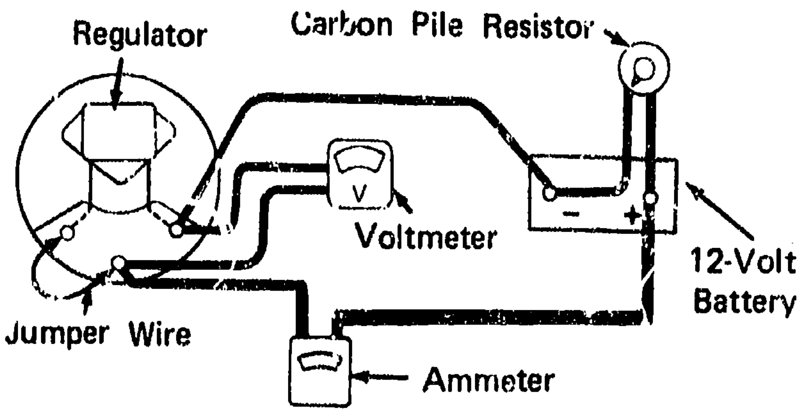
(NOTE: For a particular test procedure, always follow the equipment technical manual.)

1. Test regulator voltage.

   (NOTE: This test can be performed either on or off the machine. Use an alternator that is known to be in good repair.)

   a. Set up the test circuit. (Figure 1)

   FIGURE 1



JOB SHEET #4

b. Connect a voltmeter to the alternator ground and output terminals. (Figure 1)

(NOTE: Be sure to use a voltmeter with an accuracy within 0.1 volts.)

c. Start the engine; momentarily connect jumper wire to excite the field, and apply a load of about 10 amperes — use lights, motors, carbon pile resistors, etc.

d. Operate the circuit for about 15 minutes to stabilize the temperature of the regulators.

e. Measure and record the temperature about one inch from the regulator case.

f. Compare the voltmeter reading with the voltage specifications listed in the machine service manual.

g. Adjust the reading for the temperature recorded above.

2. Adjust transistorized regulator.

a. Use adjusting screw to change the operating voltage for different conditions.

(NOTE: This may not be used on some transistorized regulators.)

b. Since most transistorized regulators are sealed units, repair by replacing if they are found faulty.

ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #5 — TEST AN S.I. SERIES ALTERNATOR

A. Tools and materials

1. Vehicle
2. Voltmeter
3. Ammeter 0-75 amp rating or higher
4. Carbon pile
5. Screwdriver
6. Clean shop towels
7. Basic shop tools
8. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop safety procedures.)

1. Test the battery.

   (NOTE: For valid tests, the battery must be at least half charged and in good condition.)

2. Check alternator drive belt tension, and adjust as necessary.

3. Check all charging system wiring for defects and all terminal connections for cleanliness and tightness.

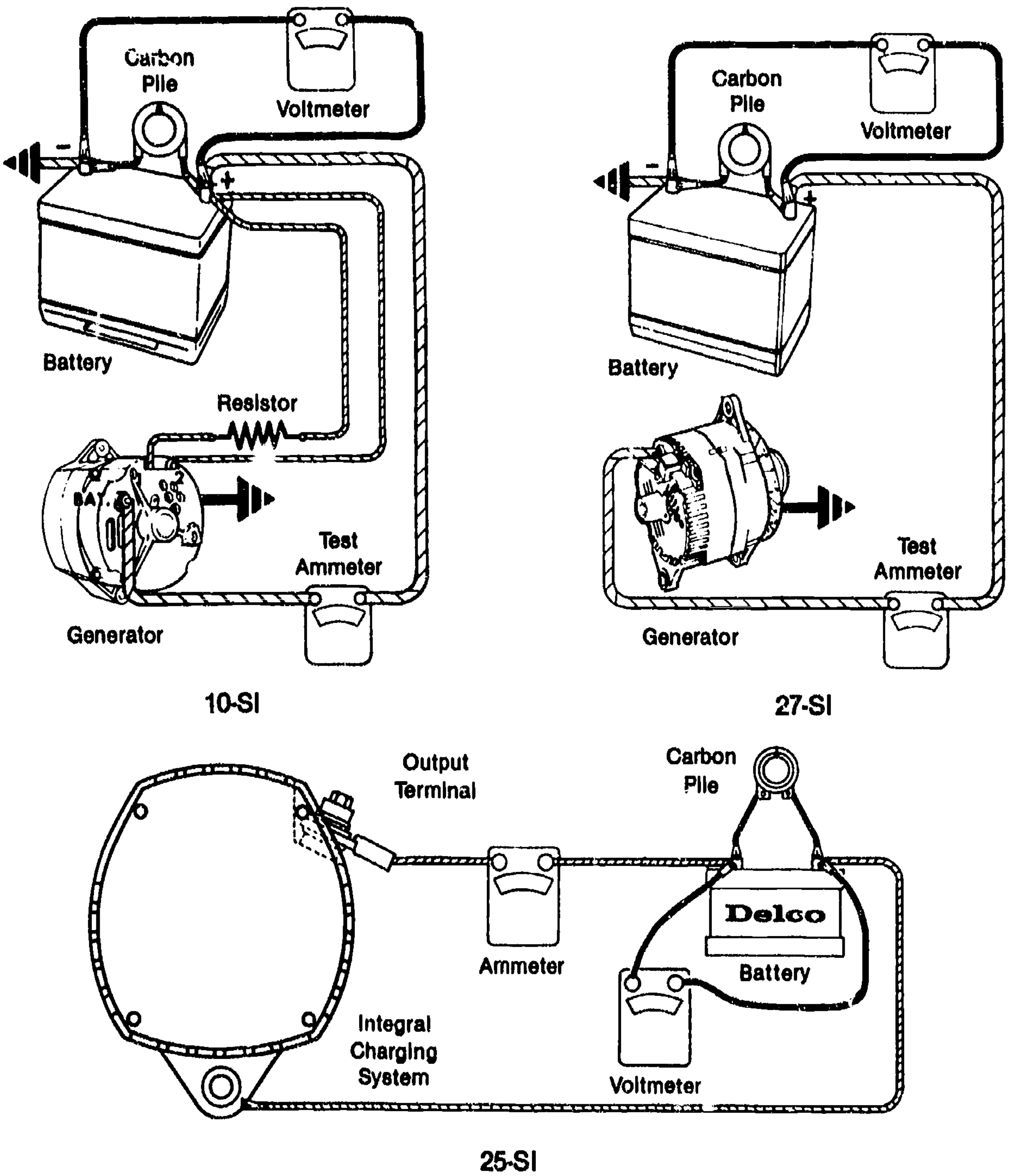
   (NOTE: If all the above steps are satisfactory, check the alternator with the following procedure.)

4. Disconnect battery ground cable.

JOB SHEET #5

5. Make test instrument connections for the type of alternator to be tested, as shown in Figure 1.

FIGURE 1



Reprinted with permission of Delco Remy Division, GM Corp.

(NOTE: The hex bolt on the output terminal on the 25-SI alternator is electrically insulated.)

JOB SHEET #5

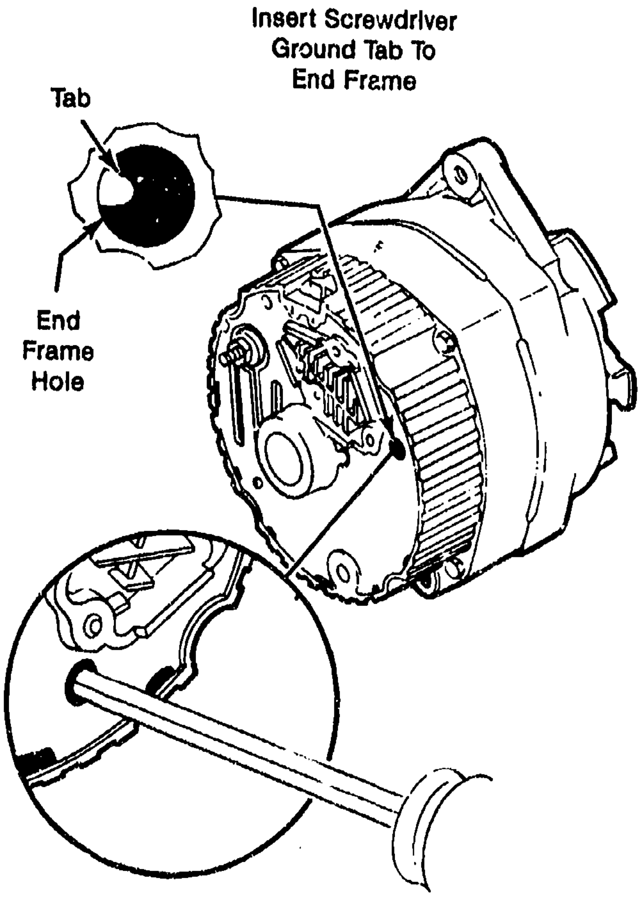
6. Operate engine at moderate speed, and adjust the carbon pile rheostat as required to obtain maximum current output.

   (NOTE: If ammeter reading is within 10 amps of rated output, the alternator and regulator are not defective. If ammeter reading is not within 10 amps of rated output, bypass regulator to see if the alternator or regulator is at fault.)

7. Bypass regulators on 10-SI and 27-SI alternators. (Figure 2)

   (NOTE: Ground the field winding by inserting a screwdriver into the test hole.)

FIGURE 2



Courtesy of Oldsmobile Division, General Motors Corporation.

(CAUTION: Tab is within ¾ inch [19.. mm] of the casting surface. Do not force screwdriver deeper into the end frame; severe damage to the alternator could result.)

JOB SHEET #5

8. Bypass regulator on a 25-SI alternator.

    a. Remove field coil leads from the regulator.

    b. Ground one field lead and connect the other field lead to battery voltage.

9. Operate engine at moderate speed, and adjust carbon pile rheostat to obtain maximum current output.

    (NOTE: If current output is within 10 percent of rated output, replace the voltage regulator. If current output is not within 10 percent of rated output, remove alternator and bench test field windings, rectifier, and stator.)

10. Turn engine off and disconnect all test instruments.

ALTERNATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #6 — TEST CHARGING CIRCUIT RESISTANCE FOR GM ALTERNATOR

A. Tools and materials

1. Vehicle
2. Basic tool set
3. Voltmeter
4. Ammeter
5. Jumper wire
6. Safety glasses
7. Appropriate service manual

B. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system, and follow all shop procedures.)

(NOTE: This job sheet is adaptable to the Ford charging circuit covered in Job Sheet #1.)

1. Test wiring for 10 D.N. alternators.

   a. Test wire going to #3 terminal of the regulator by connecting voltmeter.

      (NOTE: High resistance in this line will cause the alternator voltage to be high.)

      1) Connect a voltmeter as indicated by V1. (Figure 1 or Figure 2)

         (NOTE: Circuit #1 is for indicator light charging systems, and circuit #2 is for charging systems using an ammeter.)

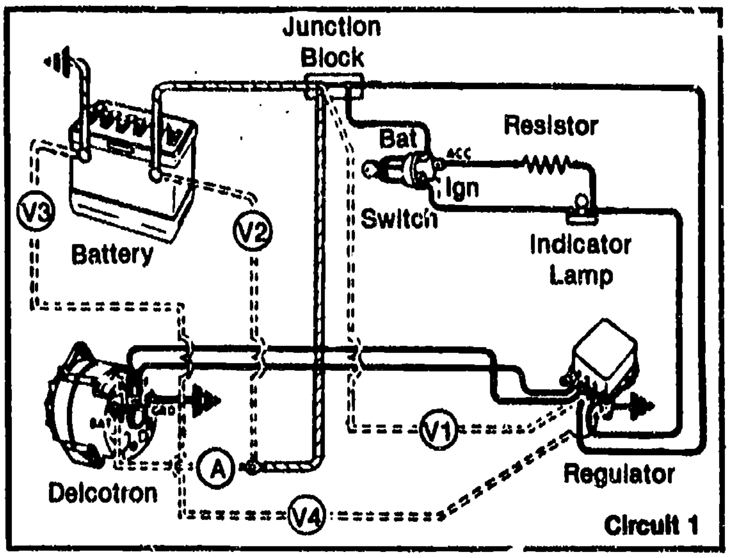
JOB SHEET #6

2) Energize the field relay.

a) Connect a jumper wire from the #3 terminal to the #. terminal. (Figure 1)

(NOTE: This will energize the field for circuit #1.)

FIGURE 1



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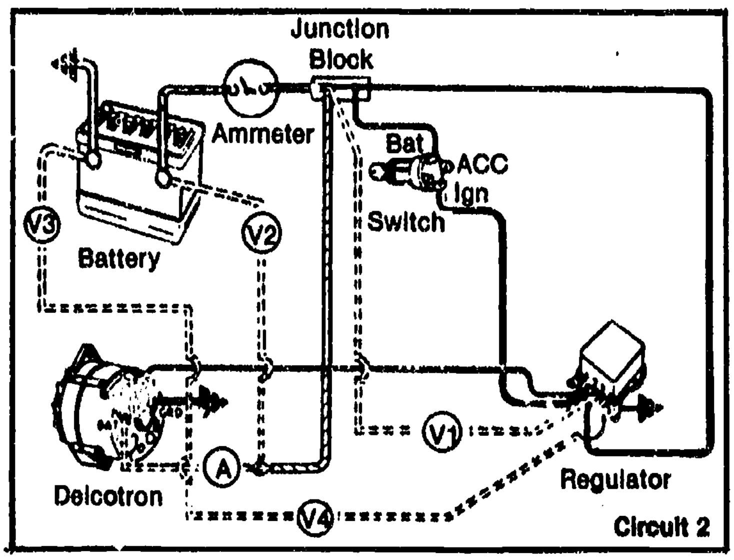
b) Turn on the ignition switch. (Figure 2)

(NOTE: This will energize the field for circuit #2.)

FIGURE 2



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b. Observe voltmeter reading.

(NOTE: The voltage drop should not exceed .3 volts.)

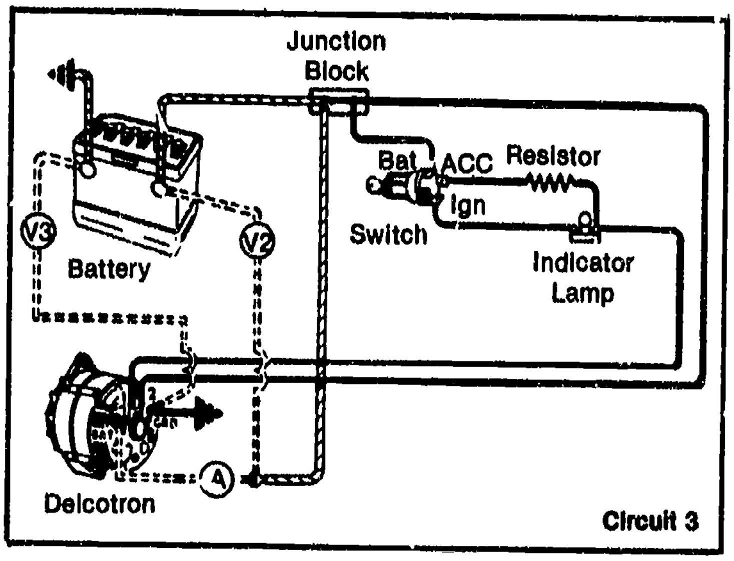
JOB SHEET #6

2. Test voltage drop between the alternator output terminal and the battery.

   a. Connect an ammeter in series with the battery terminal of the alternator. (Figure 1, 2, or 3)

   (NOTE: Figure 3 or circuit 3 features GM's SI series alternators.)

   FIGURE 3



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   b. Start the engine.

   c. Turn on enough lights and accessories to obtain a 20 ampere charge rate.

   d. Connect a voltmeter as indicated by V2 and V3. (Figures 1, 2, and 3)

   e. Observe voltmeter readings.

   (NOTE: The combined total of V2 and V3 should not exceed .8 volts.)

3. Test voltage drop in the ground circuit. (Figures 1, 2, and 3)

   a. Shut off engine, but leave lights and accessories on.

   b. Connect a voltmeter as indicated by V4. (Figure 1, 2, or 3)

   c. Observe voltmeter reading.

   (NOTE: V4 should not exceed .1 volt.)

4. Turn off lights and accessories and disconnect voltmeter.

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #1 — TEST THE FORD ALTERNATOR CHARGING CIRCUIT WITH EXTERNAL REGULATOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Tested the battery.	______	______
3. Checked and adjusted belt tension.	______	______
4. Tested alternator output.	______	______
5. Tested wiring leading to the "A" terminal of the regulator.	______	______
6. Tested wire connecting ignition switch to the regulator.	______	______
7. Tested wire connecting the "S" terminal of the alternator to the "S" terminal of the regulator.	______	______
8. Tested wire connecting the "F" terminal of the regulator to the "F" terminal of the alternator.	______	______
9. Tested regulator.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed all steps in proper sequence.				
	4	3	2	1
Student's evaluation of charging system is valid.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND REPLACE AN ALTERNATOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed battery ground.	______	______
3. Removed wire leads.	______	______
4. Removed alternator.	______	______
5. Installed alternator.	______	______
6. Installed and adjusted alternator belt.	______	______
7. Installed wire leads and tightened securely.	______	______
8. Installed battery ground cable.	______	______
9. Checked operation of alternator.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed all steps in proper sequence.				
	4	3	2	1
Alternator operates properly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #3 — DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Scribed the alternator.	______	______
3. Separated the drive and frame from the slip ring frame.	______	______
4. Removed the stator.	______	______
5. Removed the brushes and brushholder.	______	______
6. Removed heat sink.	______	______
7. Removed pulley and fan.	______	______
8. Removed rotor.	______	______
9. Tested rotor.	______	______
10. Tested the stator.	______	______
11. Tested diodes.	______	______
12. Tested diode trio.	______	______
13. Reassembled alternator.	______	______
14. Checked alternator operation.	______	______
15. Checked in/put away tools and materials.	______	______
16. Cleaned the work area.	______	______
17. Used proper tools correctly.	______	______
18. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
19. Practiced safety rules throughout procedure.	______	______
20. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed steps in proper sequence.				
	4	3	2	1
Student's evaluation of alternator components is valid.				
	4	3	2	1
Alternator operates properly.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #4 — TEST A TRANSISTORIZED REGULATOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Made all test instrument connections.	______	______
3. Started and loaded alternator 10 amperes.	______	______
4. Measured and recorded temperature of regulator.	______	______
5. Checked specification manual.	______	______
6. Adjusted voltage regulator.	______	______
7. Replaced regulator.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUC'. EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed steps in proper sequence.				
	4	3	2	1
Regulator operates correctly.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perfc.rm job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #5 — TEST AN S.I. SERIES ALTERNATOR

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	____	____
2. Tested the battery.	____	____
3. Checked alternator belt.	____	____
4. Checked wiring.	____	____
5. Disconnected battery ground.	____	____
6. Made test instrument connections.	____	____
7. Operated engine and tested alternator output.	____	____
8. Bypassed voltage regulator.	____	____
9. Turned off engine and disconnected test instruments.	____	____
10. Checked in/put away tools and materials.	____	____
11. Cleaned the work area.	____	____
12. Used proper tools correctly.	____	____
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	____	____
14. Practiced safety rules throughout procedure.	____	____
15. Provided satisfactory responses to questions asked.	____	____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed steps in proper sequence.				
	4	3	2	1
Student's evaluation of the charging system is valid.				
	4	3	2	1
Alternator operates properly.				

EVALUATOR'S COMMENTS: ______________________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

PRACTICAL TEST
JOB SHEET #6 — TEST CHARGING CIRCUIT RESISTANCE FOR GM ALTERNATOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Tested wire going to the #3 terminal of the regulator.	______	______
3. Tested wire going to the alternator output terminal.	______	______
4. Tested voltage drop in the ground circuit.	______	______
5. Turned off lights to accessories and disconnected voltmeter.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Student performed steps in proper sequence.				
	4	3	2	1
Student's evaluation of wiring is adequate.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

NAME ______________________ SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Wire coil wrapped around an iron core and mounted on a rotating shaft	1. Brushless alternator
_____b.	Laminated soft iron ring with three groups of coils	2. Diode
_____c.	Device that allows current to flow in one direction and blocks current in opposite direction	3. Grounded circuit
_____d.	Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft	4. Heat sink
_____e.	Wire touching another wire and providing a shorter path for current to flow	5. Open circuit
_____f.	Circuit in which a wire is broken or disconnected	6. Potentiometer
_____g.	Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit	7. Rectifier bridge
_____h.	Fully electronic unit composed of resistors, diodes, zener diodes, transistors, and thermistor	8. Rotor
_____i.	Dissipates heat from diodes	9. Short circuit
_____j.	An alternator that has neither slip rings nor brushes	10. Slip rings
_____k.	Acts as a voltage divider or voltage adjustment	11. Stator
_____l.	Six diodes mounted in one assembly	12. Transistorized regulator

2. State the purpose of the alternator charging circuit.

____

____

TEST

3. Match of alternator charging circuit components on the right with their correct functions.

_____a.	Starts the circuit by supplying spark to start engine, helps out during peak operation when electrical load is too much for alternator, and stabilizes system voltage	1. Alternator
_____b.	Measures the rate of current flow	2. Ammeter
_____c.	Supplies electrical power to accessory circuits and recharges battery	3. Battery
_____d.	Indicates produced voltage	4. Indicator lights
_____e.	Limits the alternator voltage to a safe, preset value	5. Regulator
_____f.	Indicates problems in system; used in place of a meter	6. Voltmeter

4. Identify the major parts of an alternator.

a. ______________________

b. ______________________

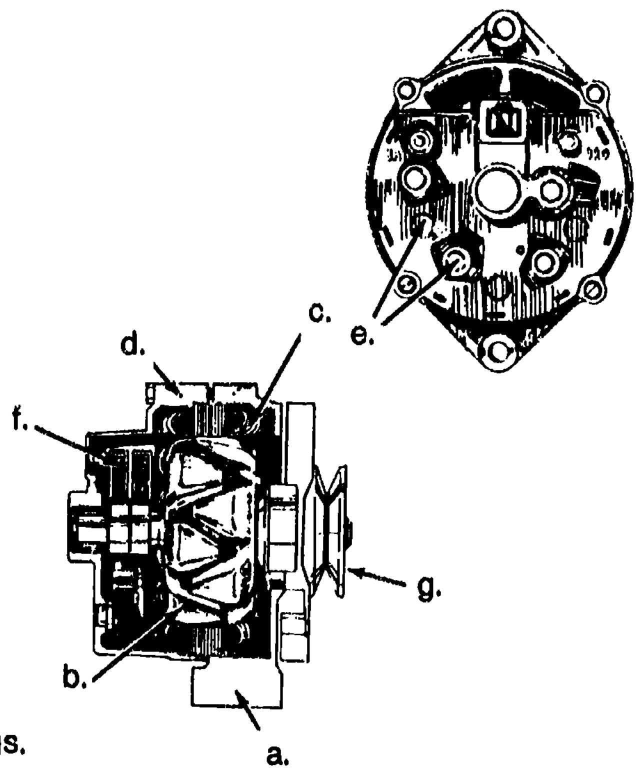
c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________



5. Discuss the construction of stator windings.

____

____

____

TEST

6. Distinguish between types of alternator circuits by placing an "E" next to the description of an external regulator.

_____a. Field current is regulated before it gets to the rotor, and the field is grounded in the alternator. When the field is grounded in the alternator, it is called a "B" circuit.

_____b. Field current is regulated after it goes through the rotor, and the field is grounded through the regulator. When the field is grounded in the regulator, it is called an "A" circuit.

7. Select from the following list characteristics of a brushless alternator by placing an "X" beside each correct characteristic.

_____a. Is a low mileage unit

_____b. Is used on diesel engines only

_____c. Regulator compartment is non-vented

_____d. Uses large bushings at both ends

_____e. Has extra large grease reservoirs

_____f. Has extra small lip seal to keep grease in, and dirt out

_____g. Regulator compartment is air tight

_____h. Designed to operate between engine overhauls without attention

8. Select true statements concerning operation of a brushless alternator by placing an "X" beside each statement that is true.

_____a. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings.

_____b. The field coil is mounted to the end frame.

_____c. The rotor is mounted on bearings and fits between the stator and field coil.

TEST

_____d. The field coil produces a north pole at the right hand side of the coil.

_____e. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles.

_____f. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand, south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path.

_____g. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings.

9. Select true statements concerning operation of a transistorized regulator by placing an "X" beside each statement that is true.

_____a. Allows battery current to excite the alternator field coils

_____b. Controls charging voltage at safe values during operation by requesting the field current

10. Complete the following statements concerning safety rules for working with alternator charging circuits by inserting the word(s) that best completes each statement.

a. Never attempt to ____________ the circuit.

b. Be sure the battery is in good operating condition before making any tests or ____________.

c. Never operate the alternator in an ____________ circuit, except when instructed in the technical manual.

d. Never ____________ or ground the alternator terminals.

e. Do not disconnect the voltage regulator while the alternator is ____________.

f. Disconnect the ____________ battery cable first when removing the alternator or battery.

g. Do not use acid-core solder on the alternator terminals; use only a ____________ core solder.

h. Never immerse the circuit components in ____________ solution.

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Demonstrate the ability to:

    a. Test the Ford alternator charging circuit with external regulator. (Job Sheet #1)

    b. Remove and replace an alternator. (Job Sheet #2)

    c. Disassemble, test, and reassemble an alternator. (Job Sheet #3)

    d. Test a transistorized regulator. (Job Sheet #4)

    e. Test an S.I. series alternator. (Job Sheet #5)

    f. Test charging circuit resistance for G.M. alternators. (Job Sheet #6)

ALTERNATOR CHARGING CIRCUITS
UNIT VII

ANSWERS TO TEST

1.
a.	8	e.	9	i.	4
b.	11	f.	5	j.	1
c.	2	g.	3	k.	6
d.	10	h.	12	l.	7

2. The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment.

3.
a.	3	d.	6
b.	2	e.	5
c.	1	f.	4

4. a. Drive end frame
   b. Rotor assembly
   c. Stator assembly
   d. Slip ring end frame
   e. Diodes
   f. Brush assembly
   g. Pulley

5. Windings have three phases which are connected together to form a "Y" or delta connection, with each winding connected to a positive and negative diode.

6. a

7. e, g, h

8. a, b, c, d, e, f, g

9. a, b

10. a. Polarize
    b. Adjustments
    c. Open
    d. Short
    e. Running
    f. Negative
    g. Rosin
    h. Cleaning

11. Performance skills evaluated to the satisfaction of the instructor.

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to troubleshoot a shut-down and alarm circuit. Competencies will be demonstrated by completing the job sheet and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to emergency shut-down circuits with their correct definitions.
2. Select true statements concerning characteristics of a coolant temperature switch-gauge.
3. Select true statements concerning characteristics of an oil pressure switch-gauge.
4. Arrange in order steps in the operation of the magnetic switch.
5. Select true statements concerning shut-off solenoids.
6. Complete statements concerning characteristics of the overspeed contactor switch.
7. Select true statements concerning the oil pressure contactor switch.
8. Complete statements concerning the operation of an alarm system.
9. Demonstrate the ability to troubleshoot a shut-down and alarm circuit. (Job Sheet #1)

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedures outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss safety procedures pertaining to emergency shut-down circuits.

2. Take a field trip to at least 3 different truck stops to see different types of shut-down circuits.

   (NOTE: Shut-down circuits can also be found anywhere that emergency generators are located, such as, in hospitals, in shopping centers, on combines, and on irrigation systems.)

3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Swichgage® Diagnostic General Catalog 1987-88.* Tulsa, OK: Frank W. Murphy Manufacturer.

B. *Operating and Maintenance Manual, Engine Models 3500 Mark II and 3700 Mark II Power Unit.* Harvey, IL: Allis-Chalmers, 1984.

SUGGESTED SUPPLEMENTAL RESOURCES

Filmstrip

Alarm Switches and Shutoffs (93 slides)
Order #JEG02702
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

INFORMATION SHEET

I. **Terms and definitions**

A. Flow control switch — Senses coolant flow through system and warns operator of immediate shut-down

B. Magnetic switch — Same as a solenoid but does not have an activating device

C. Murphy switch — An automatic shut-down switch for coolant, oil, and fuel systems

D. Normally closed switch (NC) — A switch that is activated by an electrical signal to shut down a device or an engine

E. Normally open switch (NO) — A switch that is activated either manually or electrically and returns to the open position when released

F. Overspeed governor — Protects engine from excessive rpm

(NOTE: This is also known as an overspeed trip.)

G. Solenoid — An electric coil with a moveable iron core; when current flows through the coil, it forms a magnet, and the iron core moves to activate a device

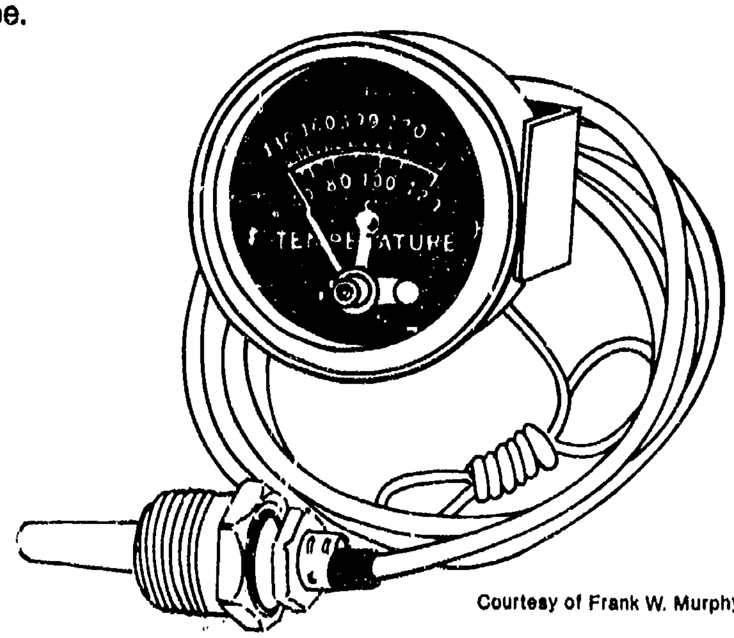
H. Switch — Electrical or mechanical device that opens or closes a circuit

I. Temperature sending unit — Monitors engine coolant temperature

II. **Characteristics of a coolant temperature switch-gauge** (Transparencies 1 and 3)

A. A combination coolant temperature gauge and safety switch

B. Connected directly into engine cooling system by a heat bulb and capillary tube.

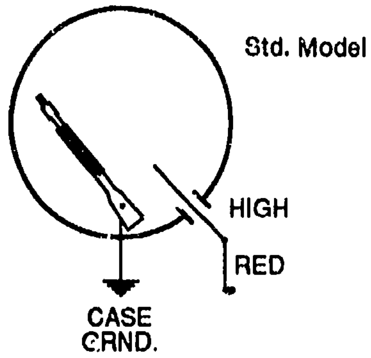


Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

INFORMATION SHEET

C. The contacts in the switch-gauge react according to their design.

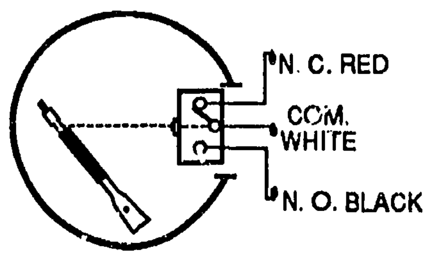
1. One wire, contact pointer type — The pointer contacts the high coolant temperature adjustment screw grounding the switch gauge.



Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma

2. Three wire, micro switch type — The contacts open to de-energize the circuit.

ESR Model



Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

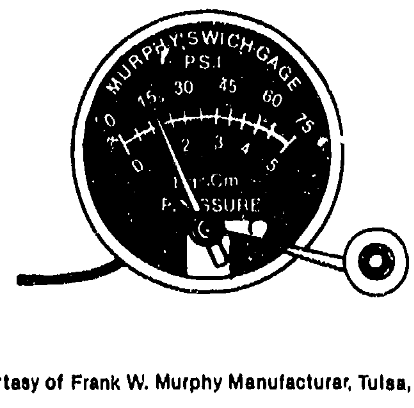
D. The gauges are adjusted at the factory to shut off the engine when the coolant temperature reaches 205-210°F.

(NOTE: This setting can be changed by using the 1/16" hex head wrench or small screwdriver and turning the adjustment screw.)

III. **Characteristics of an oil pressure switch gauge** (Transparencies 1 and 2)

A. A combination oil pressure gauge and safety switch

B. Connected by a tube directly to the engine oil gallery pressure

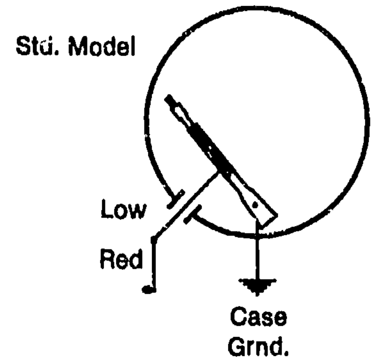


Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

INFORMATION SHEET

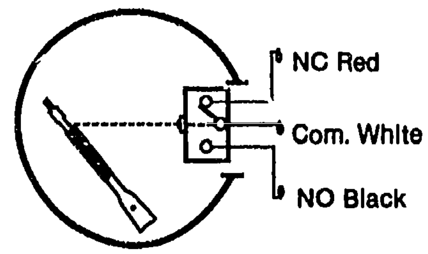
C. The contacts in the switch-gauge react according to their design.

1. One wire, contact pointer type — The pointer contacts the low oil pressure adjustment screw, grounding the switch-gauge.



Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

2. Three wire, micro switch type — The contacts open to de-energize the circuit.



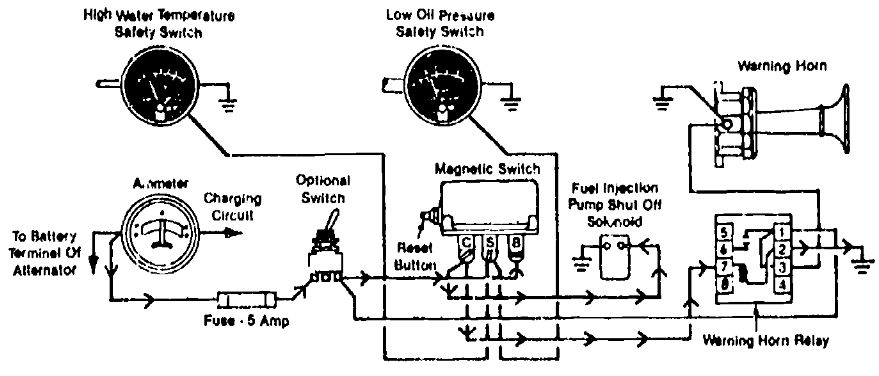
Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

D. Adjusted at the factory to shut down the engine when oil pressure drops below 10 to 12 psi

(NOTE: This setting can be changed by using a 1/16" hex head wrench or small screwdriver to turn adjusting screw.)

IV. Operation of the magnetic switch

A. Wired into the circuit of the safety controls; supplies current to open fuel shut-off solenoid.

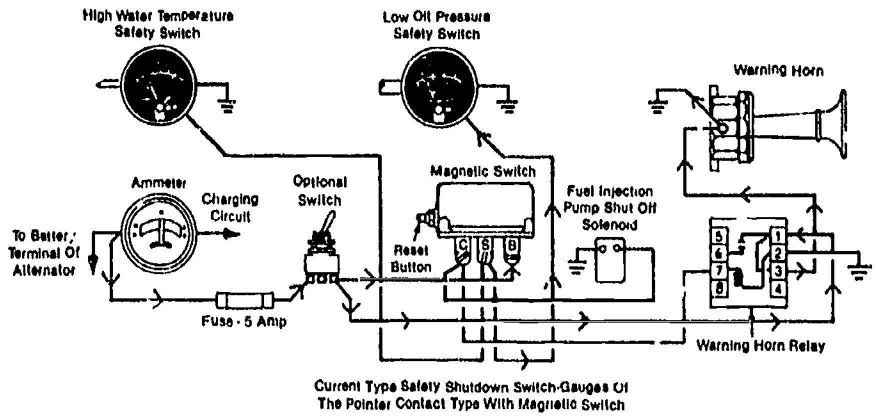


Current Type Safety Shutdown Switch-Gauges Of The Pointer Contact Type With Magnetic Switch

Courtesy of Deutz-Allis Corporation.

INFORMATION SHEET

B. Whenever the pointer of any safety-gauge makes contact and completes a circuit, it will momentarily energize the coil in the magnetic switch, releasing the armature and opening the circuit to the fuel shutoff solenoid, stopping the engine.



Courtesy of Deutz-Allis Corporation.

C. When the problem has been corrected, the reset button must be pressed in before the engine can be started.

V. **Shut-off solenoids**

A. Energized by any of the following:

1. Water temperature contactor switch or switch-gauge
2. Oil pressure contactor switch or switch-gauge
3. Overspeed contactor switch
4. Manual control switch

B. Work by overriding the governor and moving the fuel rack to the shut-off position

C. Shut off fuel supply

D. Shut off air supply.

VI. **Characteristics of the overspeed contactor switch** (Transparency 3)

A. It is mounted to the tachometer drive.

B. When the engine overspeeds, the contact points close and send a signal to the shut-off solenoid.

C. If the overspeed contactor switch is activated, it will have to be reset.

INFORMATION SHEET

VII. **Oil pressure contactor switch** (Transparencies 3 and 4)

A. Is an electric switch

B. Signals the shut-off solenoid

C. On automatic start-stop systems, a double set of contacts opens to disconnect the starter solenoid.

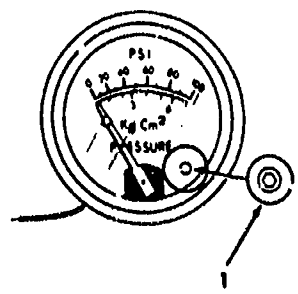
VIII. **Operation of an alarm system** (Transparency 5)

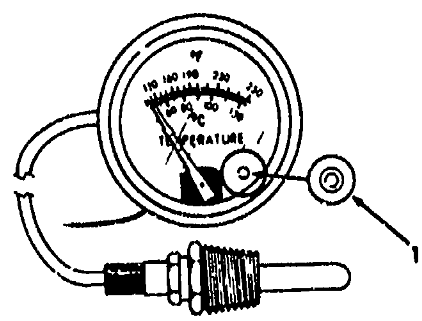
A. Uses a light in the dash to warn driver of system failure

B. Uses a horn to warn driver of system failure

C. Has to be reset after engine has been stopped

Types of Switch Gauges

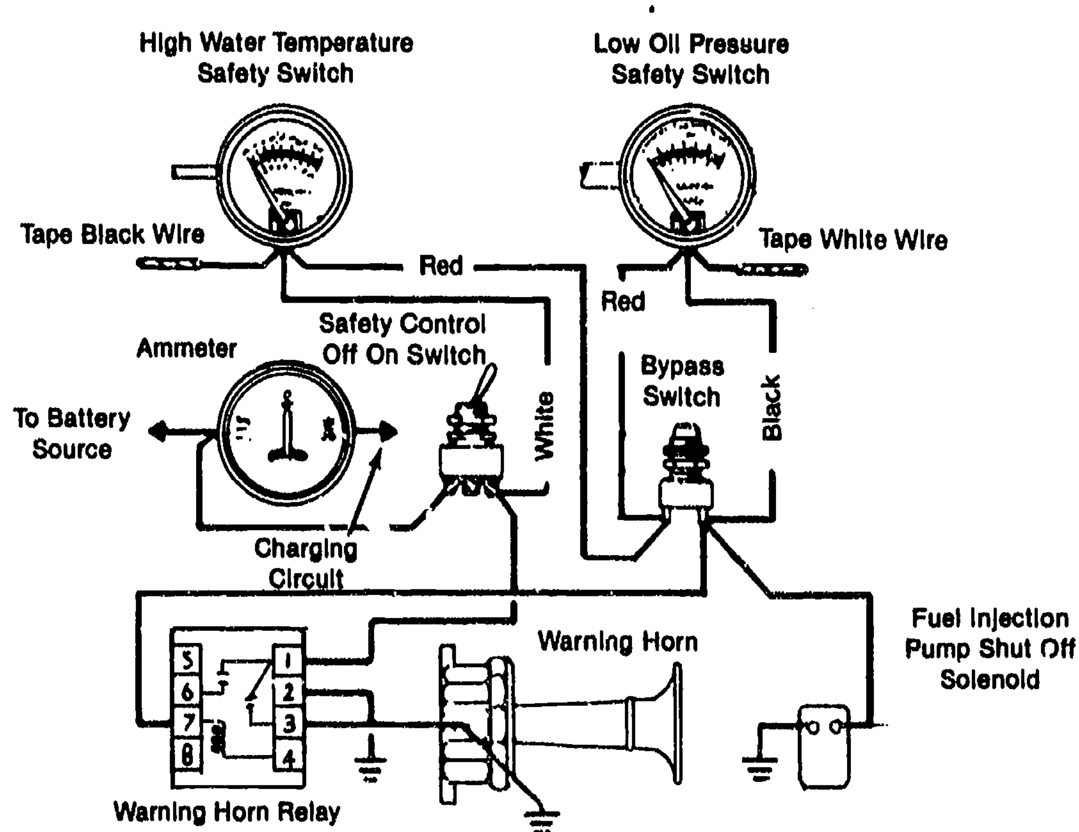




Oil Pressure

Water Temperature

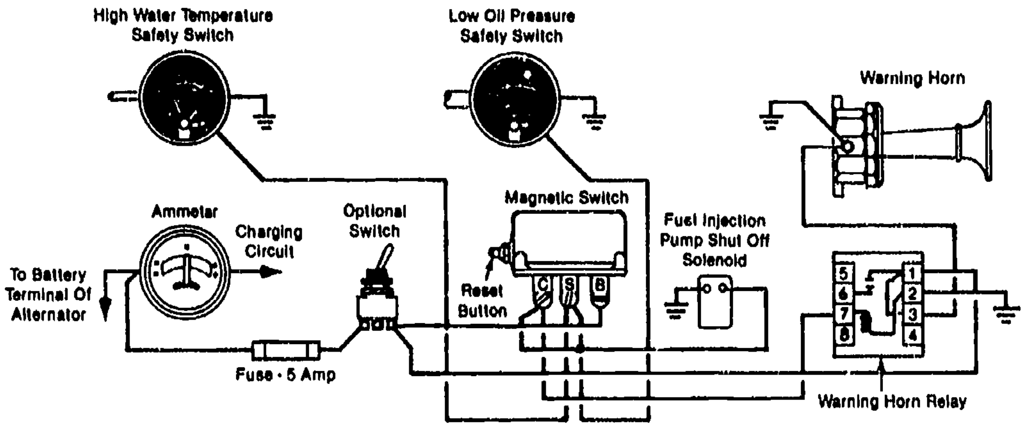
Micro
Switch Type



Switch Gauges Used With Bypass Switch

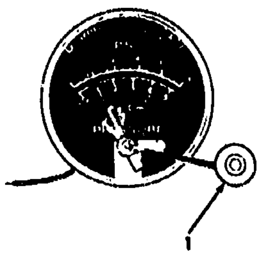
Courtesy of Deutz-Allis Corporation.

Types of Switch Gauges
(Continued)

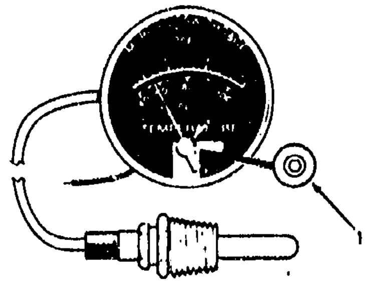


Current Type Safety Shutdown Switch-Gauges Of The Pointer Contact Type With Magnetic Switch

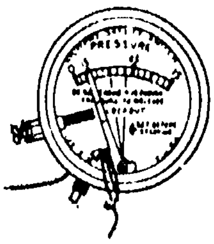
Pointer
Contact Type



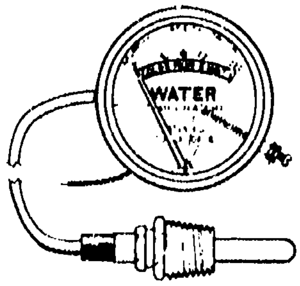
Oil Pressure



Water Temperature



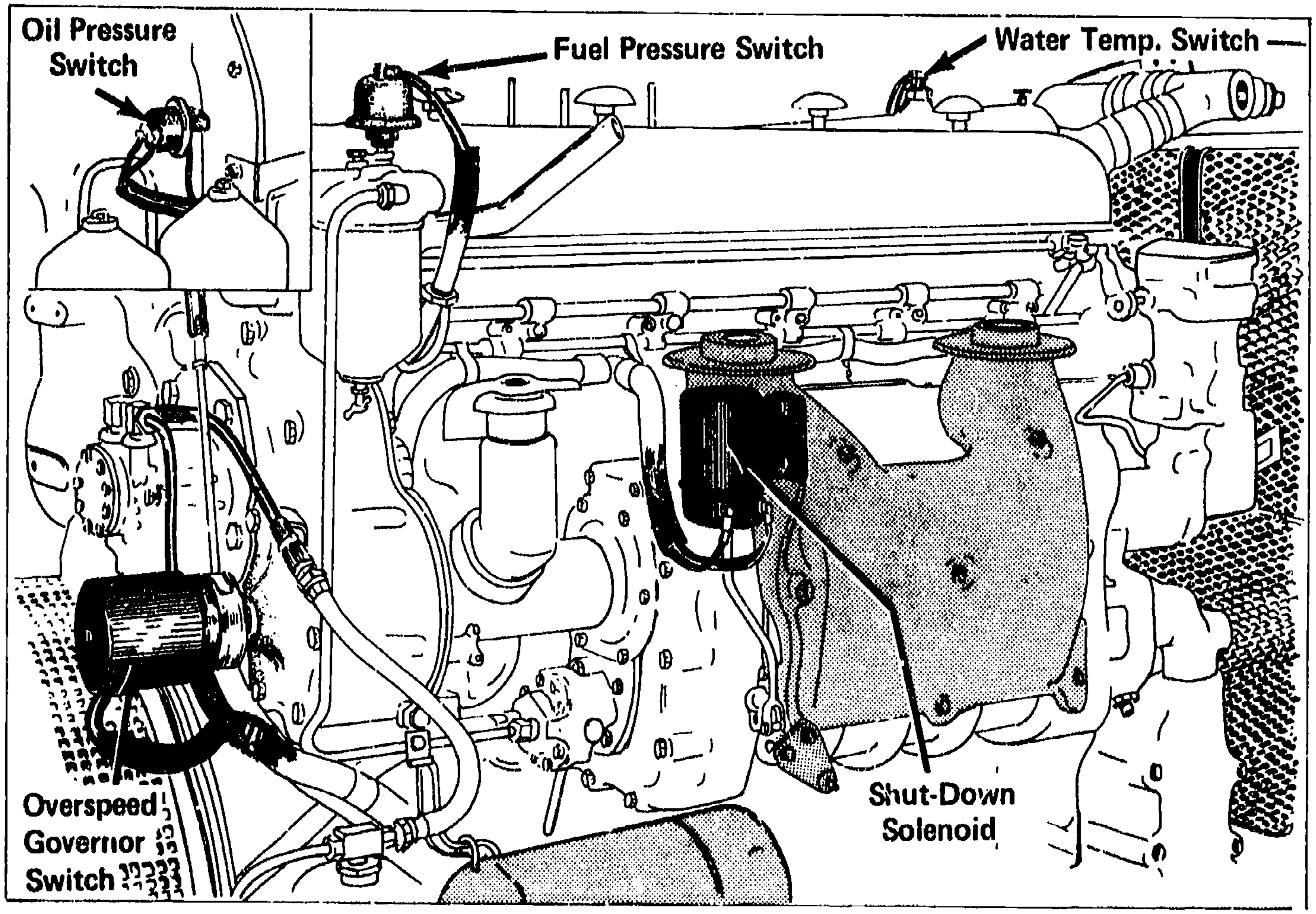
Oil Pressure



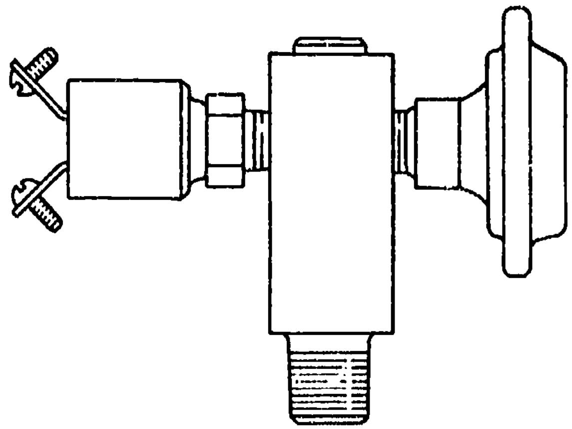
Water Temperature

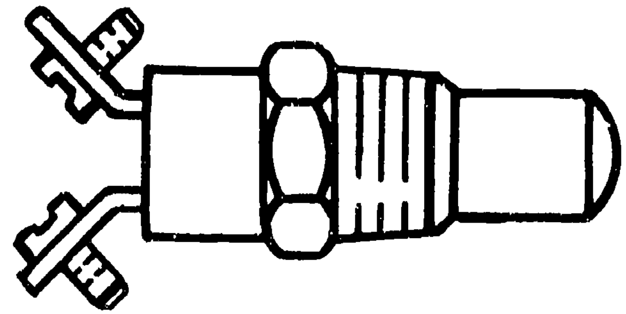
Courtesy of Deutz-Allis Corporation.

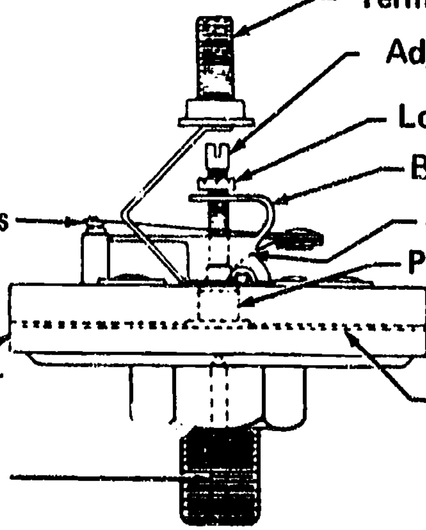
Automatic Shut-Down Device



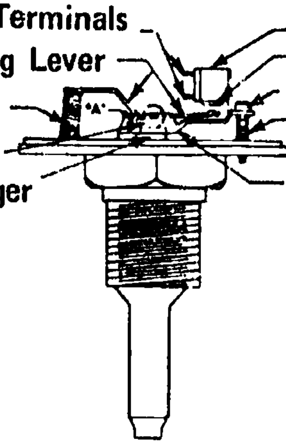
Typical Shut-Down Switches
(Continued)





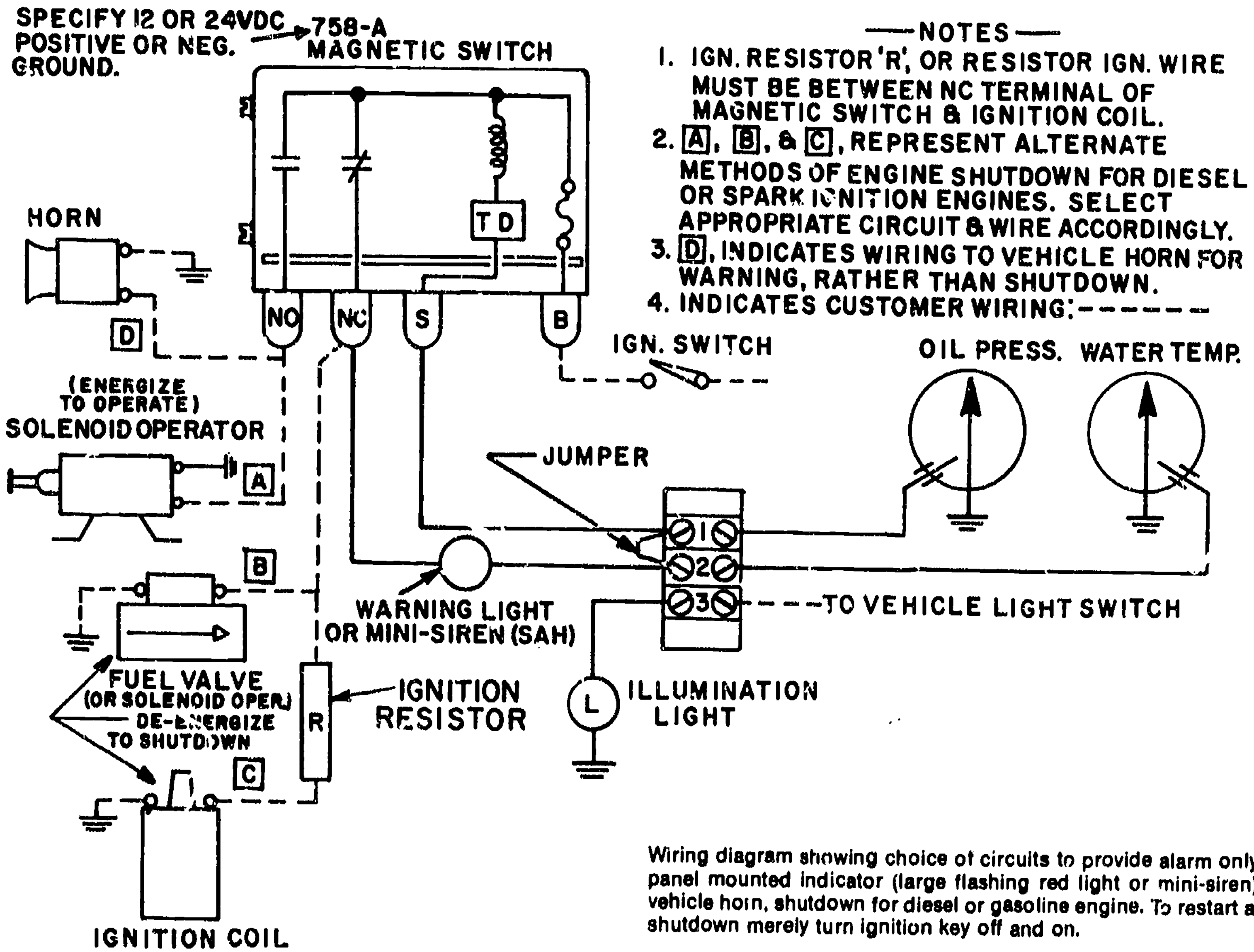


Oil Pressure Switch



Low Water Temperature Switch

Alarm Systems



Wiring diagram showing choice of circuits to provide alarm only by panel mounted indicator (large flashing red light or mini-siren) or vehicle horn, shutdown for diesel or gasoline engine. To restart after shutdown merely turn ignition key off and on.

Courtesy of Frank W. Murphy Manufacturer, Tulsa, Oklahoma.

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

JOB SHEET #1 — TROUBLESHOOT A SHUT-DOWN AND ALARM CIRCUIT

A. Tools and materials

1. Vehicle
2. Basic hand tool set
3. Circuit tester
4. Clean shop towels
5. Jumper wire with alligator clips
6. Appropriate service manual

B. Procedure

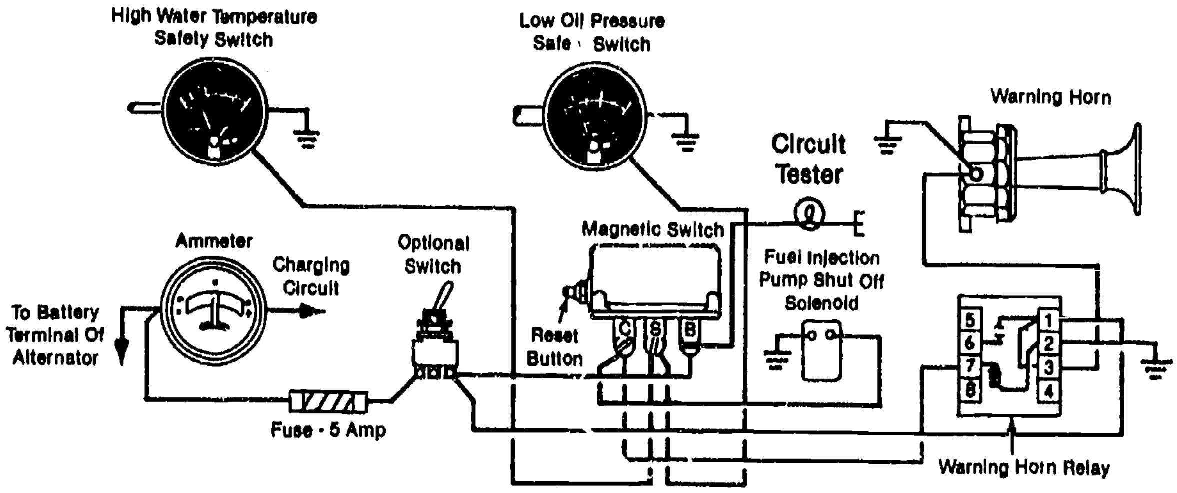
(CAUTION: Remove all jewelry before working on any electrical circuit, and follow all shop safety procedures.)

(NOTE: The following covers Murphy's 20 series Swichgages® and #117 magnetic switch. The wiring and the type of magnetic switch will differ for various applications. Refer to the service manual.)

1. Turn on optional switch and check for voltage at the "B" terminal on the magnetic switch. (Figure 1)

   (NOTE: If there is no voltage, replace fuse or repair wiring.)

   FIGURE 1



Current Type Safety Shutdown Switch-Gauges Of The Pointer Contact Type With Magnetic Switch

Courtesy of Deutz-Allis Corporation.

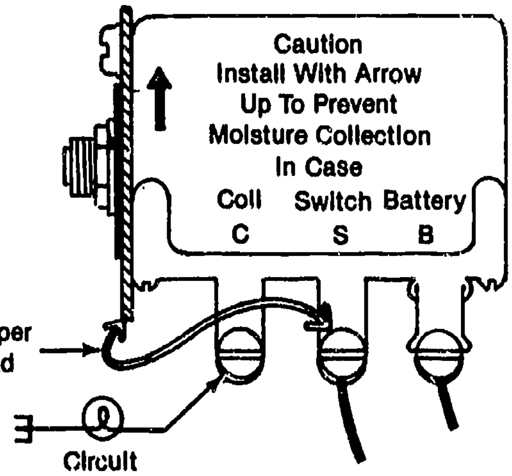
JOB SHEET #1

2. Ground the "S" terminal of the magnetic switch.

3. Test voltage at the "C" terminal of magnetic switch. (Figure 2)

   (NOTE: If there is voltage at the "C" terminal, repair or replace magnetic switch.)

FIGURE 2



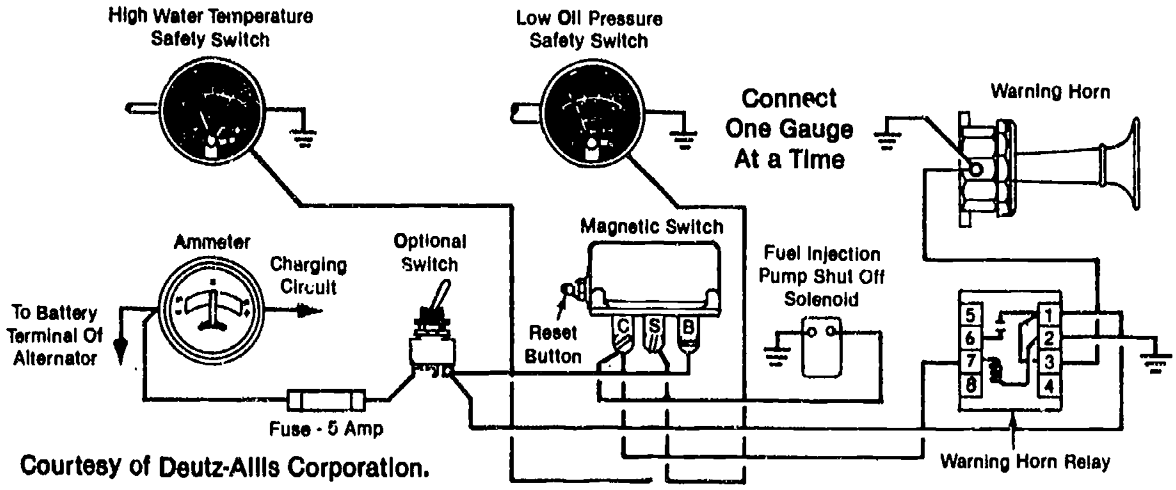
Courtesy of Deutz-Allis Corporation.

4. Disconnect wires from the "S" terminal of the magnetic switch and start engine.

5. Connect the switch-gauges to the "S" terminal of the magnetic switch one at a time. (Figure 3)

   (NOTE: If engine stops, repair or replace the circuit or gauge that is at fault.)

FIGURE 3



Courtesy of Deutz-Allis Corporation.

6. Test voltage at the fuel shut off solenoid.

   (NOTE: If there is no voltage, replace or repair wiring or magnetic switch. If there is voltage and solenoid is not working, check ground circuit; if it is okay, replace solenoid.)

JOB SHEET #1

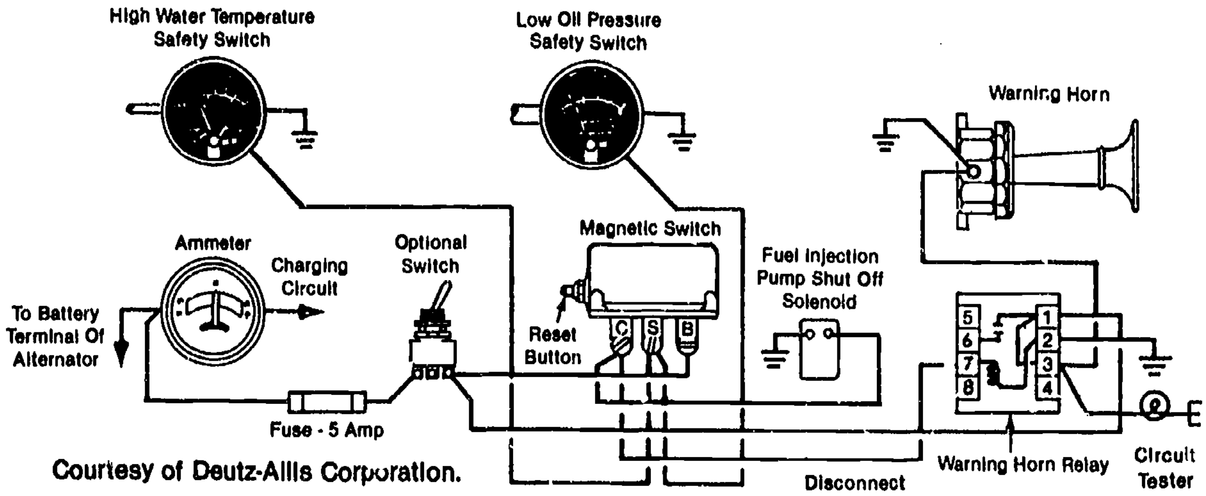
7. Test voltage in the wire going from the optional switch to the horn relay.

   (NOTE: If there is no voltage, repair or replace circuit.)

8. Disconnect the wire going from the "C" terminal of the magnetic switch to the horn relay. (Figure 4)

   (NOTE: If the horn does not operate, check voltage in wire going from the relay to the horn. If voltage is not present, replace horn relay.)

FIGURE 4



Courtesy of Deutz-Allis Corporation.

9. Test horn by connecting voltage to the insulated terminal.

   (NOTE: If horn doesn't operate and the ground circuit is good, replace or repair horn.)

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

PRACTICAL TEST
JOB SHEET #1 — TROUBLESHOOT A SHUT-DOWN AND ALARM CIRCUIT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked for voltage at the "B" terminal.	______	______
3. Tested for voltage at the "C" terminal.	______	______
4. Checked switch-gauges and wiring.	______	______
5. Tested fuel shut-off solenoid.	______	______
6. Tested horn relay.	______	______
7. Tested horn.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Problem in the circuit is found and repaired.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

NAME ______________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

_____a.	Electrical or mechanical device that opens or closes a circuit	1. Flow control switch
_____b.	Same as a solenoid but does not have any activating device	2. Magnetic switch
_____c.	An electric coil with a moveable iron core; when current flows through the coil, it forms a magnet, and the iron core moves to activate a device	3. Murphy switch
_____d.	Monitors engine coolant temperature	4. Normally closed switch
_____e.	A switch that is activated either manually or electrically and returns to the open position when released	5. Normally open switch
_____f.	A switch that is activated by an electrical signal to shut down a device or an engine	6. Overspeed governor
_____g.	Senses coolant flow through system and warns operator of immediate shut-down	7. Solenoid
_____h.	Protects engine from excessive rpm	8. Switch
_____i.	An automatic shut-down switch for coolant, oil, and fuel systems	9. Temperature sending unit

2. Select true statements concerning characteristics of a coolant temperature switch-gauge by placing an "X" beside each statement that is true.

_____a. A combination coolant temperature gauge and safety switch

_____b. On the one wire, contact pointer gauge, when the pointer contacts the high coolant temperature adjustment screw, it opens the switch-gauge.

_____c. On the three wire, micro switch, the contacts close to de-energize the circuit.

_____d. The gauges are adjusted at the factory to shut off the engine when the coolant temperature reaches 205 - 210°F.

TEST

3. Select true statements concerning characteristics of an oil pressure switch-gauge by placing an "X" beside each statement that is true.

   _____a. A combination oil pressure gauge and safety switch

   _____b. Connected by a tube directly to the engine air breather

   _____c. The contacts in the switch-gauge are all the same

   _____d. Adjusted at the factory to shut down the engine when the oil pressure rises above 10 to 12 psi

4. Arrange in order the steps in the operation of the magnetic switch.

   _____a. Whenever the pointer of any safety-gauge makes contact and completes a circuit, it will momentarily energize the coil in the magnetic switch, releasing the armature and opening the circuit to the fuel shutoff solenoid, stopping the engine.

   _____b. Wired into the circuit of the safety controls; supplies current to open fuel shut-off solenoid

   _____c. When the problem has been corrected, the reset button must be pressed in before the engine can be started.

5. Select true statements concerning shut-off solenoids by placing an "X" beside each statement that is true.

   (NOTE: A statement is true only if all parts of the statement are true.)

   _____a. Energized by any of the following:

      1) Water temperature contactor switch or switch-gauge
      2) Oil pressure contactor switch or switch-gauge
      3) Overspeed contactor switch
      4) Manual control switch

   _____b. Work by overriding the governor and moving the control switch to the shut-off position

   _____c. Shut off fuel supply

6. Complete the following statements concerning characteristics of the overspeed contactor switch by inserting the word that best completes each statement.

   a. It is mounted to the ____________ drive

   b. When the engine overspeeds, the contact points ____________ and send a signal to the shut-off solenoid.

   c. If the overspeed contactor switch is not activated, it will have to be ____________.

TEST

7. Select true statements concerning the oil pressure contactor switch by placing an "X" beside each statement that is true.

   _____a. Is an electric switch

   _____b. Signals the shut-off solenoid

   _____c. On automatic start-stop systems, a double set of contacts closes to disconnect the starter solenoid.

8. Complete the following statements concerning the operation of an alarm system.

   a. Uses a light in dash to warn driver of ______________________________

   b. Uses a ____________ to warn driver of system failure

   c. Has to be reset after ______________________________

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

9. Demonstrate the ability to troubleshoot a shut-down and alarm circuit. (Job Sheet #1)

EMERGENCY SHUT-DOWN CIRCUITS
UNIT VIII

ANSWERS TO TEST

1. a. 8
   b. 2
   c. 7
   d. 9
   e. 5
   f. 4
   g. 1
   h. 6
   i. 3

2. a, d

3. a

4. a. 2
   b. 1
   c. 3

5. a, c

6. a. Tachometer
   b. Open
   c. Reset

7. a, b

8. a. System failure
   b. Horn
   c. Engine has been stopped

9. Performance skills evaluated to the satisfaction of the instructor